July 2022

2022 MINNESOTA TRANSPORTATION ASSET MANAGEMENT PLAN

MINNESOTA GO

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395 John Ireland Boulevard
Saint Paul, Minnesota 55155

July 18, 2022

Mr. Wendall Meyer
Division Administrator
Federal Highway Administration – Minnesota Division
180 East 5th Street, Suite #930
St. Paul, Minnesota 55101

Dear Mr. Meyer,

The Minnesota Department of Transportation is pleased to submit the 2022 Minnesota Transportation Asset Management Plan (TAMP). Minnesota's 14,000-mile highway system is critical to the state's economic competitiveness and Minnesotans' 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 a continued commitment to efficiently managing the State's transportation assets.

This TAMP meets the Moving Ahead for Progress in the 21st Century Act and subsequent Federal rulemaking 23 CFR, part 515 requirements. The changes to Title 23 United States Code (U.S.C.), Section 119(e)(4), that took effect on October 1, 2021, because of the Bipartisan Infrastructure Law, are also reflected in this TAMP.

The TAMP results from a collaborative effort guided by a Steering Committee with representation from specialty offices and districts, senior leadership and the Federal Highway Administration Minnesota Division staff. We particularly appreciate the support and guidance provided by the FHWA staff as we worked our way through this process and look forward to your final approval and certification.

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

Sincerely,

Nancy Daubenberger

Nancy Daubenberger, P.E.
Commissioner

cc: Peter Eakman, FHWA

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TABLE OF CONTENTS

CHAPTER 1
INTRODUCTION 1

CHAPTER 2
ASSET MANAGEMENT PLANNING AND PROGRAMMING FRAMEWORK 7

CHAPTER 3
ASSET INVENTORY, CONDITION AND VALUATION 17

CHAPTER 4
ASSET MANAGEMENT PERFORMANCE MEASURES, TARGETS AND PERFORMANCE GAPS 39

CHAPTER 5
RISK MANAGEMENT 53

CHAPTER 6
LIFE CYCLE PLANNING 83

CHAPTER 7
FINANCIAL PLANNING 139

CHAPTER 8
TAMP IMPLEMENTATION 157

APPENDIX A
RISK TIERS AND GLOSSARY 165

APPENDIX B
TAMP RISK REGISTER 173

APPENDIX C
LIFE CYCLE PLANNING 183

INTRODUCTION

The Minnesota Department of Transportation owns and operates 14,000 miles of state highway that include various critical assets in its right of way. This transportation network is vital to Minnesota's economic competitiveness and quality of life. Maintaining a high level of asset performance makes the system safer and more reliable for Minnesotans. 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 guide its plans, projects and investment strategies. The Transportation Asset Management Plan (TAMP) continues this legacy. MnDOT's TAMP is an accountability and communication tool. It also informs capital and operations planning efforts. In addition to being a federal requirement, the TAMP helps MnDOT further evaluate risks, develop mitigation strategies, analyze life cycle planning, establish asset condition performance measures and targets, and develop investment strategies.

MnDOT is recognized nationally as a leader in asset management. MnDOT integrates the TAMP into its long-term planning processes, includes assets beyond the federal minimum requirements, uses an enterprise approach to managing risk and annually invests in business processes and analysis to advance asset management.

ASSET MANAGEMENT VISION AND OBJECTIVES

MnDOT initiated a strategic planning process for asset management after completing the 2019 TAMP. The final plan, called the Asset Management Strategic Implementation Plan, provides direction for improving the management of highway assets over the next five years. It sets a vision for asset management at MnDOT and establishes near-term objectives. The TAMP planning process uses the AMSIP vision and objectives, which are listed below.

Vision for Asset Management
To effectively manage transportation assets by mitigating risks, optimizing return on investment and using the best available information and tools.

ASSET MANAGEMENT OBJECTIVES

- Use data effectively to strategically manage investments and assets, within available resources, in a proactive and holistic way to reduce life-cycle costs and maintain the value of MnDOT's most critical assets.
- Improve the ability to evaluate trade-offs between investment options in a consistent and transparent way that maximizes system performance.
- Integrate asset management into MnDOT's culture through effective communication and a workforce with the skills needed to successfully fulfill their asset management duties and responsibilities.

2022 TAMP DEVELOPMENT PROCESS

This 2022 TAMP builds on previous versions of the TAMP and includes several process refinements and additions. Highlighted improvements include:

- Partnered with a consultant to advance MnDOT life cycle planning for each asset class.
- Created a risk management glossary to guide and work towards shared language while discussing risk.
- Enhanced the cross-asset risk prioritization process with MnDOT's Asset Management Steering Committee and TAMP Advisory Group.
- Added information to the asset risk register.
- Enhanced integration between risk management and investment decision making using the Enterprise Risk Management framework.
- Added substantial content on resilience that highlights what MnDOT is doing to manage extreme weather events through risk management and life cycle planning.

TAMP DEVELOPMENT TEAM

The TAMP planning process involved internal staff from asset-expert work groups, a project management team, a TAMP Advisory Group and Asset Management Steering Committee feedback. These groups were instrumental in advancing the TAMP from previous iterations and were responsible for the process improvements listed above.

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

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

MnDOT's **TAMP Advisory Group** coordinated and communicated asset management planning across the agency, particularly to district staff. This group convenes as-needed to make decisions from a cross-asset perspective.

MnDOT's **Asset Management Steering Committee** provided high-level direction and oversight during TAMP development and all broad agency asset management activities. This committee includes representation throughout the agency, including at the assistant commissioner level, and from Minnesota's Federal Highway Administration division office.

ASSETS INCLUDED IN THE TAMP

The 2022 TAMP includes federally required pavement and bridge assets. It also contains 10 additional assets, categorized as “other assets,” which include asset sub-groups.

REQUIRED ASSETS

- Pavements
- Bridges (including Bridge Culverts)

OTHER ASSETS

- Buildings
- Highway Culverts
- Deep Stormwater Tunnels
- Intelligent Transportation Systems
- Noise Walls
- Overhead Sign Structures
- Pedestrian Infrastructure
- Traffic Signals
- Lighting
- High-Mast Light Towers

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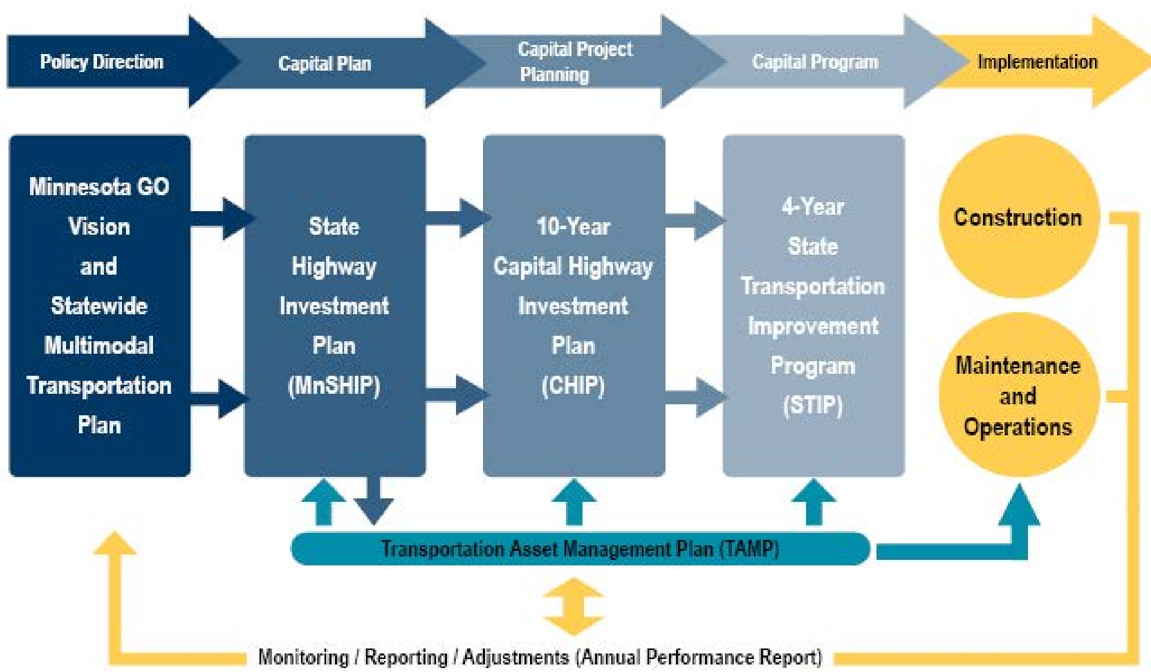
ASSET MANAGEMENT PLANNING AND PROGRAMMING FRAMEWORK

MnDOT has robust business processes to prioritize asset management investments in Minnesota's transportation infrastructure. MnDOT asset management guides the effective use of available resources to make the right investment decisions and minimize asset life cycle costs while considering the various trade-offs involved in decision-making processes. This is consistent with the definition of asset management outlined in the Moving Ahead for Progress in the 21st Century act:

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 MnDOT's planning and programming process, showing the link between the existing agency plans and the Transportation Asset Management Plan, is represented in Figure 2-1.

Figure 2-1: MnDOT Planning Process



This chapter will further describe how policy direction guides the planning and programming framework as well as walk through each plan to highlight how the TAMP is integrated within MnDOT's planning and programming framework.

MINNESOTA GO VISION

MnDOT's long-term (50-year) Minnesota GO Vision is to create a multimodal transportation system that maximizes the health of people, the environment and economy. The Minnesota GO Vision provides guiding principles for MnDOT policy and investment decisions. Beneath this overarching policy direction, there are plans with different roles. They connect to transportation asset management but have different relationships with the TAMP.

Figure 2-2: Minnesota GO Vision and guiding principles

MINNESOTA'S MULTIMODAL TRANSPORTATION SYSTEM MAXIMIZES THE HEALTH OF PEOPLE, THE ENVIRONMENT AND OUR ECONOMY.

The system:

- Connects 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 country.
- Provides safe, convenient, efficient and effective movement of people and goods.
- Is flexible and nimble enough to adapt to changes in society, technology, the environment and our economy.

Quality of Life

- Recognizes and respects the importance, significance and context of place—not just as destinations, but also where people live, work, learn, play and access services
- Is accessible regardless of socioeconomic status or individual ability

Environmental Health

- Is designed in such a way that it enhances the community around it and is compatible with natural systems
- Minimizes resource use and pollution

Economic Competitiveness

- Enhances and supports Minnesota's role in a globally competitive economy as well as the international significance and connections of Minnesota's trade centers
- Attracts human and financial capital to the state

GUIDING PRINCIPLES

The Minnesota GO principles guide policy and investment decisions for all forms of transportation throughout Minnesota. The guiding principles that most relate to the TAMP are shown in Figure 2-3.

Figure 2-3: Select Guiding Principles

PRINCIPLES	DESCRIPTION
Leverage Public Investments to Achieve Multiple Purposes	The transportation system should support other public purposes, such as environmental stewardship, economic competitiveness, public health and energy independence.
Build to a Maintainable Scale	Consider and minimize long-term obligations–don't overbuild. The scale of the system should reflect and respect the surrounding physical and social context of the facility. The transportation system should affordably contribute to the overall quality of life and prosperity of the state.
Integrate Safety	Systematically and holistically improve safety for all forms of transportation. Be pro-active, innovative and strategic in creating safe options.
Strategically Fix the System	Some parts of the system may need to be reduced while other parts are enhanced or expanded to meet changing demand. Strategically maintain and upgrade critical existing infrastructure.
Use Partnerships	Coordinate across sectors and jurisdictions to make transportation projects and services more efficient.

STATEWIDE MULTIMODAL TRANSPORTATION PLAN

MnDOT's Statewide Multimodal Transportation Plan, adopted in 2017, identifies objectives and strategies to help achieve the Minnesota GO Vision. The plan emphasizes multimodal solutions that ensure a high return on investment. SMTP objectives identify overarching guidance and priorities for the entire transportation system. The strongest connection to asset management is the System Stewardship objective. The objectives are shown in Figure 2-4. The SMTP is currently being updated with an adoption anticipated in fall 2022.

Figure 2-4: Statewide Multimodal Transportation Plan 2017 Objectives

SMTP OBJECTIVE	SUMMARY
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 through which the system travels. Apply proven strategies to reduce fatalities and serious injuries for all modes. Foster a culture of transportation safety in Minnesota.
Critical Connections	Maintain and improve multimodal transportation connections essential for Minnesotans' prosperity and quality of life. Strategically consider new connections that help meet performance targets and maximize social, economic and environmental benefits.
Healthy Communities	Make fiscally responsible transportation system decisions that respect and complement the natural, cultural, social and economic context. Integrate land use and transportation to leverage public and private investments.
System Stewardship	Strategically build, manage, maintain, and operate all transportation assets. Rely on system data and analysis, performance measures and targets, agency and partners' needs and public expectations to inform decisions. Use technology and innovation to get the most out of investment and maintain system performance. Increase the resiliency of transportation system and adapt to changing needs.

MINNESOTA STATE HIGHWAY INVESTMENT PLAN

MnDOT documents its capital investment strategies to address all five of the above SMTP objectives in the Minnesota State Highway Investment Plan. MnSHIP is a 20-year plan that analyzes and tracks the impact of recent capital investments, identifies capital needs, establishes statewide priorities for projected revenue, and identifies strategies that ensure that MnDOT efficiently uses resources.

The 2018-2037 plan estimates revenues for the next 20 years to total $21 billion, although the projected needs on the transportation system total $39 billion. The plan identified needs in excess of anticipated revenues.

Due to this investment gap, the MnSHIP investment direction focuses on maintaining the existing state highway system with limited mobility investments. MnDOT strives to optimize a return on investment, reduce life-cycle costs, evaluate investment trade-offs with greater transparency and communicate asset management principles throughout the agency. This approach aligns with TAMP's asset management vision stated in **Chapter 1: Introduction**. MnSHIP is currently being updated and a new investment direction will be available in 2023.

CAPITAL HIGHWAY INVESTMENT PLAN

The 10-year Capital Highway Investment Plan is updated annually to communicate MnDOT's proposed capital investments for the next 10 years. It also helps MnDOT check planned investments against the MnSHIP guidance.

MnDOT starts identifying potential projects as far as 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 the state highway system. District staff and specialty office staff use the asset management strategies and principles identified in the TAMP to prioritize and select these projects. MnDOT then combines the district lists into the 10-Year Capital Highway Investment Plan.

MAINTENANCE WORK PLANNING

MnDOT's construction crews are responsible for a wide variety of maintenance activities. Asset conditions and weather impacts change those priorities daily and sometimes hourly. Even though emergencies cannot be planned, there is an opportunity to use asset inspection data, performance measure targets, and historical operation demands to perform transparent scenario planning that can optimize maintenance activities and document trade off decisions.

MnDOT developed performance measures for multiple maintenance activities, including crack filling roadways, resetting culvert aprons and mowing. The measures do not include asset condition, which is impacted more by capital expenditure, nor do they include maintenance quality assurance, which would require additional staff to measure the demand.

TAMP IN THE PLANNING PROCESS

The TAMP does not replace any existing MnDOT plan. Instead, it helps existing plans link capital and maintenance expenditures to assets. The TAMP also informs future iterations of MnDOT plans. For instance, the next MnSHIP will incorporate work from the 2022 TAMP. The annual CHIP update includes investment strategies identified in the TAMP. MnDOT also uses the TAMP to analyze life cycle costs, evaluate risks, develop mitigation strategies, establish asset condition performance measures and targets, and develop investment strategies. Additionally, the TAMP will serve as an accountability and communication tool to inform established capital and operations planning efforts.

PROJECT SELECTION POLICY

In 2017, the Minnesota Legislature directed MnDOT to develop and implement a new transparent and objective project selection policy for construction projects on the state highway system. The project selection policy was first implemented with the 2020-2023 State Transportation Improvement Program and 2020-2029 Capital Highway Investment Plan.

The policy requires that MnDOT use scores to prioritize and select highway construction projects. The scores inform project selection decisions, but MnDOT may consider other factors in addition to the score. MnDOT selects projects within various categories and programs. Each category and program has a separate process to evaluate, prioritize and select projects.

Broadly, these categories and programs include:

- **Asset management:** the rehabilitation and replacement of pavement, bridges and other infrastructure.
- **Targeted safety improvements:** enhancements to reduce the number of crashes and people injured or killed on Minnesota state highways.
- **Mobility and capacity expansion:** improvements to traffic flow, congestion relief and travel time reliability, freight movement, or creating new connections for active transportation users such as people walking and bicycling.

Each broad category has sub-categories within which projects are evaluated and selected. For example, pavement projects are scored and prioritized separately from bridge projects. MnDOT also manages a variety of special programs with specific objectives, which typically do not fund asset management projects. MnDOT posts all candidate projects, scoring methodologies and project selection reasoning at MnDOT's project Selection website.

Once a project is selected, MnDOT develops and evaluates alternatives to address the identified need and other legal requirements, opportunities to advance legislative goals, objectives in state plans, and other repairs and improvements that make sense to do at the same time. The department follows a complete streets approach, which considers the needs of all the different types of vehicles and people who will use the road or bridge. MnDOT balances the identified needs and opportunities against the funding guidance of MnSHIP and looks for cost-effective and affordable solutions. MnDOT also works with local and regional partners, metropolitan planning organizations, tribal governments and regulatory agencies, and seeks public input during the project's development.

ENTERPRISE ASSET MANAGEMENT SYSTEMS

HIGHWAY PAVEMENT MANAGEMENT APPLICATION

The Highway Pavement Management Application is software that meets all federal minimum standards for developing and operating pavement management systems. The software creates funding scenarios based on pavement treatment decision trees and performance prediction models to optimize the combination of preservation and rehabilitation activities and achieve the best conditions possible given funding constraints. This process is explained further in **Chapter 7: Financial Planning**.

MnDOT's roadway network is kept up to date using ESRI's Roads and Highways database management system. The condition of the network is measured annually by MnDOT's pavement management unit using a special digital inspection vehicle equipped with an inertial profiler, 3D laser camera system, laser height sensors, digital video imaging system and GPS antenna. This vehicle drives all state highways (including interstate routes) in both directions annually. The data is processed to calculate distress, roughness, rutting, faulting and cracking. As projects are completed, staff update the HPMA.

Each segment of road in HPMA has unique deterioration curves used to predict future conditions. HPMA uses a regression fit through all the data collected since the last major rehabilitation if there is enough historical data for the segment. Each segment of road in HPMA has predicted conditions 50 years beyond the current state.

After modeling the future condition, each section of the road goes through a treatment decision model. The decision model identifies a fix based on the predicted condition, age and traffic for each year of the analysis period. This determines various treatments, effectiveness and cost. HPMA removes treatments that do not meet the user-entered constraints (e.g., financial constraints). The result of the analysis is a set of recommended projects, anticipated cost and expected impact on the condition of the network.

MnDOT will be transitioning from the HPMA pavement management software to the Transportation Asset Management System in 2023. In addition to moving away from a software application that is no longer supported, the move will eliminate multiple manual processes that combine data from various sources and provide a single-system solution for pavement and maintenance management.

BRIDGE REPLACEMENT AND IMPROVEMENT MANAGEMENT SYSTEM

MnDOT follows the National Bridge Inspection Standards, the Specification for the National Bridge Inventory Bridge Elements and the MnDOT Bridge and Structure Inspection Program Manual for requirements surrounding the collection of bridge data. MnDOT's Bridge Replacement and Improvement Management System is software that helps MnDOT make bridge investments. The software follows federal minimum standards for developing and operating a bridge management system, but also expands the effort to provide additional value in areas that MnDOT deems necessary.

Bridge inventory and condition data are stored in the Structure Information Management System. This database also includes National Highway System bridges owned by other agencies. The SIMS database feeds MnDOT reporting and analysis tools, including the national AASHTOWare Bridge Management software.

The current central decision-making tool for MnDOT Bridge investments is BRIM which consumes bridge inventory and inspection data so that users can view, analyze and make decisions based on customized logic principals developed by MnDOT practices and procedures. BRIM is also used to forecast future bridge conditions by applying deterioration curves that were developed based on aggregation of historical deck inspection data.

Life cycle cost principles are built into the assignment of work types within BRIM and the repair strategies outlined in the Bridge Preservation and Improvement Guidelines. The treatment logic in BRIM provides a recommended work type, timeframe and cost for each bridge. The treatment options include a mixture of preservation, rehabilitation and replacement alternatives that consider the remaining life in the bridge. The timings of these treatments are based on current condition, design details, site considerations and predicted deterioration.

Unit costs are applied to each bridge based on the recommended work type and bridge quantities. Expert review refines the work based on the latest information and allows the districts to match bridge work with pavement (or other) work on a corridor. The work grouping minimizes the number of roadway closures.

The results of the decision tree determinations are presented to engineering and planning staff for consideration annually. The recommended project type, timeframe and costs are either accepted or overridden based on the intimate knowledge of maintenance and operations staff. The result is used to develop short-term budget needs for the STIP and CHIP and long-term budget needs for the MnSHIP 20-year plan. BRIM data is also used to provide a list of candidate projects if surplus funding becomes available and to forecast the future condition of the system based on varying investment amounts. This aids in steering MnSHIP investment levels but also provides insight for how to set Federal Bridge Condition Performance Targets.

TRANSPORTATION ASSET MANAGEMENT SYSTEM

Transportation Asset Management System was first developed in 2016 for signals, lighting, and ITS assets. It has since added a variety of other assets, including hydraulic infrastructure and sign structures.

At its most basic, TAMS allows reporting and mapping of asset data and historical maintenance expenditures. This information creates cost models for life cycle cost evaluations, maintenance demand estimates and performance evaluation. It also improves project scoping efficiency and effectiveness. The specialized traffic signals and ITS module, and the signs management module within TAMS, allow for advanced analytics, though MnDOT is in the early stages of capitalizing on this functionality. MnDOT also has prepared a robust decision tree for highway culvert maintenance and numerous condition-based maintenance performance measures. These algorithms are programmed into TAMS, allowing network needs analysis and work planning.

TAMS is also used to maintain and update inventory information using work orders and other means such as condition inspections. MnDOT has acquired inventory and condition data for the assets mentioned above. MnDOT's Asset Management Program Office is responsible for maintaining the accuracy of TAMS. Acquiring and maintaining data requires the involvement of staff from across MnDOT. TAMS helps capital planning and project scoping, and an asset to fieldwork management will benefit from consistent and available data.

In 2023, pedestrian infrastructure will be added to TAMS. Pedestrian assets are governed by the Americans with Disabilities Act, enacted on July 26, 1990. The act is a civil rights law prohibiting discrimination against individuals based on disability. Title II of the ADA pertains to the programs, activities and services public entities provide. As a state transportation agency, MnDOT must comply with Title II of the ADA. In 2010-2012, MnDOT conducted a self-evaluation of its facilities and developed an ADA Transition Plan detailing how the organization will ensure that all its facilities, services, programs and activities are accessible to all individuals.

Currently, ADA curb and sidewalk data is a part of MnDOT's self-evaluation. The database is a geospatial collection of pedestrian facilities within its public right-of-way. The assets inventoried are curb ramps, accessible pedestrian signals, sidewalks and trails. Staff use handheld GPS units to map and collect condition data. Each year, the previous year's construction projects are re-evaluated to ensure ADA compliance.

ARCHIBUS

ARCHIBUS software tracks MnDOT-owned building assets. The Minnesota Department of Administration mandates that all state agencies maintain their building inventories. This includes custodial control and updating the floorplan drawings of those buildings. In addition, there are two other mandated uses of ARCHIBUS. First, all required Facility Condition Assessments data is entered annually into the Capital Project Management Module. This data is necessary for the agency to receive capital investment appropriations. Second, all leases between the State of Minnesota and a private or public entity are entered and maintained in the Real Estate Portfolio Management Module.

ASSET INVENTORY, CONDITION AND VALUATION

Minnesota's state highway system includes approximately 2,800 bridges and 14,000 roadway miles of interstates, US highways and Minnesota highways. Although the state highway system comprises just 8% of Minnesota's total roadway system mileage, it carries almost 60% of the vehicle miles traveled statewide, including most freight traveling by road.

In addition to pavement and bridge, the Transportation Asset Management Plan includes buildings, highway culverts, deep stormwater tunnels, intelligent transportation systems, noise walls, overhead signs, pedestrian infrastructure, traffic signals, lighting and high-mast light towers. The following sections show the inventory, condition and valuation for each of these assets.

Asset valuation assigns a monetary value to an asset based on condition, age or cost to replace. Asset value provides a benchmark to support sustainable investment. In the TAMP, the total replacement cost is assessed for each asset class. Current asset value, which accounts for the present condition or age of assets, is calculated for pavements, bridges and buildings.

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 asphalt, while rigid pavement is concrete.

Figure 3-1: Pavement Inventory, 2020

Source: HPMA. Note: Interstate and Other National Highway System does not include locally owned NHS roadways.

SYSTEM	FLEXIBLE ROADWAY MILES	RIGID ROADWAY MILES	TOTAL ROADWAY MILES	TOTAL LANE-MILES
Interstate	715	1,101	1,816	4,051
Other NHS	4,595	1,193	5,787	11,671
Non-NHS	6,513	159	6,672	13,350
TOTAL	11,823	2,453	14,276	29,072

PAVEMENT CONDITION

Figure 3-2: Pavement Condition, 2021

Source: HPMA. MnDOT Ride Quality Index.

SYSTEM	GOOD	FAIR	POOR
Interstate	92.5%	7.1%	0.4%
Other NHS	82.2%	17.3%	0.5%
Non-NHS	77.2%	20.8%	2.0%

DATA COLLECTION, MANAGEMENT AND REPORTING

DATA COLLECTION

- Data collection is automated and performed annually on all state highways and non-state owned NHS.
- Ride condition and surface distresses are collected for all roadways (only surveying the rightmost lane).
- Shoulders and ramps are not surveyed but are a part of a current research project.
- Office of Materials and Road Research is responsible for data collection.

MANAGEMENT

- Highway Pavement Management Application is used to manage inventory and condition data.
- Pavement condition deterioration models and project selection are conducted using the HPMA.
- Pavement Investment Evaluator tool calculates pavement health indicators based on current pavement conditions and planned maintenance and projects. This allows the user to edit the activities in the PIE and run different scenarios to see how the health indicators change and the impact that planned activities are expected to have on the district's pavement network.

REPORTING

- MnDOT Pavement Management Unit annually publishes Pavement condition report.
- Maps are available on MnDOT's Pavement Management web page.
- Data is reported annually to FHWA's Highway Performance Monitoring System.

PAVEMENT ASSET VALUATION

The replacement value for pavement is $1 million per lane-mile. The current asset value is the depreciated value of the pavement based on the pavement condition as measured by the Pavement Quality Index. PQI rates surface roughness and cracking on a scale of 0 to 5.

Figure 3-3: Pavement Asset Valuation

SYSTEM	TOTAL LANE-MILES	REPLACEMENT VALUE	CURRENT ASSET VALUATION (2021)	2019 ASSET VALUATION
Interstate	4,051	$4.1 billion	$3.3 billion	Not Broken Out
Other NHS	11,671	$11.7 billion	$9.2 billion	Not Broken Out
Non-NHS	13,350	$13.4 billion	$10 billion	Not Broken Out
Total (State Highway)	29,072	$29.1 billion	$22.5 billion	$22.3 billion

BRIDGES

Bridges are large, complex and expensive assets. They provide safe access to transportation users throughout the state. MnDOT's bridge inventory includes all bridge structures 10 feet and greater, including bridge culverts.

Figure 3-4: Bridge Inventory, 2021

Source: BRIM. Note: NHS does not include locally owned NHS bridges.

SYSTEM	BRIDGE COUNT	BRIDGE DECK AREA (SQ. FT.)
NHS	1,376	27,711,462
Non-NHS	1,435	20,582,582
Total (State Highway)	2,811	48,294,044

Figure 3-5: Bridge Culvert Inventory, 2021

Source: BRIM.

SYSTEM	BRIDGE CULVERT COUNT	BRIDGE CULVERT AREA (SQ. FT.)
NHS	734	2,334,676
Non-NHS	1,085	2,038,390
Total (State Highway)	1,819	4,373,066

BRIDGE CONDITION

Figure 3-6: Bridge Condition, 2020

Source: BRIM.

SYSTEM	GOOD	FAIR	POOR
NHS	32.9%	64%	3.1%
Non-NHS	32.6%	63.6%	3.8%

DATA COLLECTION, MANAGEMENT AND REPORTING

DATA COLLECTION

- Data collection is based on National Bridge Inspection Standards, American Association of State Highway and Transportation Officials and MnDOT requirements.
- Most bridges are inspected every other year in Minnesota (some more or less frequently based on inspection results).
- MnDOT Districts perform/supervise routine inspections and provide Quality Control of inspection results.
- The Central Bridge Office performs/supervises Quality Assurance of inspection results.

MANAGEMENT

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

REPORTING

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

BRIDGE ASSET VALUATION

Bridge replacement value can vary from one bridge to the next based on complexity. The average cost per square foot is $302. Current asset value is calculated based on the National Bridge Inventory inspection rating for each bridge component (deck, superstructure, substructure) and age. The NBI is on a scale of 0 to 9. Each bridge component deteriorates at a different rate and is valued differently. Bridges constructed before 1970 require upgrades to meet current design criteria.

Figure 3-7: Bridge Asset Valuation

SYSTEM	BRIDGE DECK AREA (SQ. FT.)	BRIDGE REPLACEMENT VALUE	CURRENT ASSET VALUE (2020)	2019 ASSET VALUE
NHS	27,711,462	$8.4 billion	$4.6 billion	Not Broken Out
Non-NHS	20,582,582	$6.2 billion	$3.4 billion	Not Broken Out
Total (State Highway)	48,294,044	$14.6 billion	$8 billion	$8.5 billion

For bridge culverts, the replacement value is cost per square foot with a minimum price of $225,000 per culvert.

Figure 3-8: Bridge Culverts (>10 feet) Asset Valuation

SYSTEM	BRIDGE CULVERT COUNT / SQ. FT.	BRIDGE CULVERT REPLACEMENT VALUE
NHS	734 / 2,334,676 sq ft	$352 million
Non-NHS	1,085 / 2,038,390 sq ft	$344 million
TOTAL (State Highway)	1,819 / 4,373,066 sq ft	$697 million

BUILDINGS

MnDOT owns, operates and maintains a wide variety of buildings to support the state's transportation infrastructure. These buildings vary widely in purpose, size and location and include rest areas, salt sheds and MnDOT headquarter buildings.

Figure 3-9: Building Inventory, 2021

Source: ARCHIBUS

BUILDING TYPE	COUNT	SQUARE FEET
Rest Area	50	134,925
Weigh Station	9	22,284
Truck Station (Class 2/3) – Small Truck Storage	117	1,081,198
Truck Station (Class 1)	33	2,397,575
Salt Shelter	233	1,261,839
Office Facility	10	468,459
Heated Shed	48	262,605
Unheated Shed	268	757,482
Brine Facility	49	31,879
Miscellaneous	80	84,857
Total	897	6,503,103

BUILDING CONDITION

Figure 3-10: Building Condition using the Facilities Condition Index, 2021

Source: ARCHIBUS. Note: Facility Condition Index (FCI) is calculated as the ratio of deferred maintenance to the current replacement value of the facility. The smaller the FCI, the better in the condition of the facility.

BUILDING TYPE	EXCELLENT (FCI <0.05)	GOOD (0.05< FCI <0.15)	AVERAGE (0.15<FCI <0.30)	POOR (0.30<FCI <0.50)	CRITICAL (FCI>0.50)
Rest Area	10%	58%	26%	6%	0%
Weigh Station	56%	33%	11%	0%	0%
Truck Station (Class 2/3) – Small Truck Storage	21%	38%	39%	3%	0%
Truck Station (Class 1)	15%	33%	52%	0%	0%
Salt Shelter	15%	48%	27%	7%	3%
Office Facility	0%	30%	60%	10%	0%
Heated Shed	10%	50%	33%	6%	0%
Unheated Shed	25%	50%	19%	3%	3%
Brine Facility	45%	45%	10%	0%	0%
Miscellaneous	N/A	N/A	N/A	N/A	N/A

DATA COLLECTION, MANAGEMENT AND REPORTING

DATA COLLECTION

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

MANAGEMENT

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

REPORTING

- Data is reported annually to the Minnesota Department of Administration.

BUILDING ASSET VALUATION

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

Figure 3-11: Building Asset Valuation

BUILDING TYPE	COUNT	REPLACEMENT VALUE	CURRENT ASSET VALUE (2021)	2019 ASSET VALUE
Rest Area	50	$55.3 million	$49 million	Not Broken Out
Weigh Station	9	$6.5 million	$6 million	Not Broken Out
Truck Station (Class 2/3) – Small Truck Storage	117	$208.2 million	$182 million	Not Broken Out
Truck Station (Class 1)	33	$699.2 million	$593.8 million	Not Broken Out
Salt Shelter	233	$112 million	$95.5 million	Not Broken Out
Office Facility	10	$109 million	$92.2 million	Not Broken Out
Heated Shed	48	$41.8 million	$35.4 million	Not Broken Out
Unheated Shed	268	$88.2 million	$77.6 million	Not Broken Out
Brine Facility	49	$5 million	$4.7 million	Not Broken Out
Miscellaneous	80	$34.8 million	$29.5 million	Not Broken Out
Total	897	$1.4 billion	$1.2 billion	$945 million

HIGHWAY CULVERTS AND DEEP STORMWATER TUNNELS

Highway culverts (less than 10 feet in diameter) convey surface water under highway travel lanes, ramps and loops. Deep stormwater tunnels are located in the Twin Cities metropolitan area. They collect stormwater runoff and are approximately 50-100 feet below the surface.

Figure 3-12: Highway Culvert and Deep Stormwater Tunnel Inventory, 2020

Source: TAMS

ASSET TYPE	COUNT / UNIT
Highway Culverts	38,519 (number)
Deep Stormwater Tunnels	73,101 linear feet (8 tunnels)

HIGHWAY CULVERT AND DEEP STORMWATER TUNNEL CONDITION

Figure 3-13: Highway Culvert and Deep Stormwater Tunnel Condition, 2020

Source: TAMS.

ASSET TYPE	GOOD	FAIR	POOR	CANNOT BE RATED(FCI>0.50)
Highway Culverts	17%	59%	17%	7%
Deep Stormwater Tunnels	84.4%	15.6%	0%	N/A

DATA COLLECTION, MANAGEMENT AND REPORTING

DATA COLLECTION

- Highway culverts are managed by district maintenance and hydraulics\Water Resources Engineering.
- Highway culvert inspections are dependent on a features overall condition rating and occur every one to six years. Inspections are performed in-house and through consultant contracts. Inspectors are trained each year and follow the criteria stated in the TAMS HydInfra Inspection Manual.
- Highway culvert inventory collection is an ongoing effort. Standard specifications for as-builts capture new features and repairs in projects. Maintenance work orders track any repairs or installations performed. District staff also update inventory from design plans.
- Deep stormwater tunnels are managed by MnDOT Metro District Water Resources Engineering.
- Deep stormwater tunnel inspections are based on condition and performed every two to five years. Inspections are done through consultant contract and follow the Pipeline Assessment and Certification Program developed by the National Association of Sewer Service Companies.
- Deep stormwater tunnel inventory is currently complete. WRE staff will update inventory if needed.

MANAGEMENT

- TAMS is used to track inventory, inspection and maintenance activities related to hydraulic infrastructure.

REPORTING

- Condition ratings are extracted from TAMS HydInfra system for internal reporting purposes.
- There is no official reporting for culverts or tunnels.

HIGHWAY CULVERTS AND DEEP STORMWATER TUNNELS ASSET VALUATION

A highway culvert's replacement value is $31,500 per culvert. This was determined using a condition-based depreciation method. The percentage for remaining value was based on recommendations from asset experts in conjunction with remaining life estimates in a life-cycle planning model using TAMS-HydInfra data condition. The replacement value for tunnels is approximately $6,000 per linear foot.

Figure 3-14: Highway Culverts and Deep Stormwater Asset Valuation

ASSET TYPE	COUNT / UNIT	REPLACEMENT VALUE	CURRENT ASSET VALUE (2021)	2019 ASSET VALUE
Highway Culverts	38,519 (culverts)	$1.2 billion	$900 million	$1.2 billion
Deep Stormwater Tunnels	73,101 linear feet (8 tunnels)	$452 million	$435 million	$372 million

INTELLIGENT TRANSPORTATION SYSTEMS

Intelligent Transportation System (ITS) assets are electronics, communication, 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, E-ZPASS readers, Road Weather Information Systems and other information and communication systems. The analysis performed in this TAMP accounts only for the structural condition; other functional and operational requirements (e.g., luminaire replacement) are not considered.

Figure 3-15: ITS Inventory, 2021

Source: TAMS. Note: Communication Equipment inventory is 2017 data.

ITS SUB ASSET TYPE	COUNT
Fiber Communication Network Miles	965
Fiber Network Shelters	87
Traffic Management System Cabinet	1,296
Dynamic Message Signs	352
Traffic Monitoring Cameras	1,040
Traffic Detector Stations/Site -Loops / Radar	6,688
E-ZPass Readers	57
Reversible Road Gates	29
Ramp Meters	873
Road Weather Information Systems Sites	147
Automatic Traffic Recorders Sensors	119
Weigh-In-Motion System Sites Sensors	23

ITS CONDITION

ITS condition is measured based on age. Approaching or beyond useful service life as a condition means that after a predetermined number of years, the asset is no longer useful for various reasons. In the case of ITS assets, this is usually because new technology is available, which makes existing technology antiquated.

Figure 3-16: ITS Condition, 2021

Source: TAMS.

ITS SUB ASSET TYPE	COUNT	% APPROACHING OR BEYOND USEFUL SERVICE LIFE
Fiber Communication Network Miles	965	17.2%
Fiber Network Shelters	87	1.1%
Traffic Management System Cabinet	1,296	1.9%
Dynamic Message Signs	352	12.2%
Traffic Monitoring Cameras	1,040	3.8%
Traffic Detector Stations/Site -Loops / Radar	6,688	39.0%
E-ZPass Readers	57	0%
Reversible Road Gates	29	0%
Ramp Meters	873	0%
Road Weather Information Systems Sites	147	0%
Automatic Traffic Recorders Sensors	119	0%
Weigh-In-Motion System Sites Sensors	23	0%

DATA COLLECTION, MANAGEMENT AND REPORTING

DATA COLLECTION

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

MANAGEMENT

- All ITS assets are managed in TAMS.

REPORTING

- There is no official reporting of ITS data.

ITS ASSET VALUATION

ITS asset valuation is based on the per unit cost for replacement for each asset shown in Figure 3-17.

Figure 3-17: ITS Asset Valuation

ITS SUB ASSET TYPE	COUNT	REPLACEMENT VALUE
Fiber Communication Network Miles	965	$72.3 million
Fiber Network Shelters	87	$9.5 million
Traffic Management System Cabinet	1,296	$18.1 million
Dynamic Message Signs	352	$34.2 million
Traffic Monitoring Cameras	1,040	$3.4 million
Traffic Detector Stations/Site -Loops / Radar	6,688	$22.7 million
E-ZPass Readers	57	$0.7 million
Reversible Road Gates	29	$0.2 million
Ramp Meters	873	$5.2 million
Road Weather Information Systems Sites	147	$13.2 million
Automatic Traffic Recorders Sensors	119	$4 million
Weigh-In-Motion System Sites Sensors	23	$3.5 million
Total	11,796	$187.5 million

NOISE WALLS

Noise walls reduce highway sounds for nearby communities. MnDOT conducts noise studies to assess existing noise levels and predict future noise levels based on transportation-related projects under development.

Figure 3-18: Noise Wall Inventory, 2021

Source: TAMS and FHWA Triennial Reporting. Note: 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.

WALL TYPE	COUNT	WALL AREA (SQ. FT.)
Wood	397	10,472,837
Concrete	67	1,311,217
Total	464	11,784,054

NOISE WALLS CONDITION

Figure 3-19: Noise Wall Structural Condition, 2021

Source: TAMS. Note: Inspections have not been done for walls in unknown condition. Poor and very poor walls are combined in the poor category.

ASSET TYPE	GOOD	FAIR	POOR	UNKNOWN
Noise Walls (Wood and Concrete Combined)	33.6%	42.9%	5.6%	17.9%

DATA COLLECTION, MANAGEMENT AND REPORTING

DATA COLLECTION

- Using standard specification for as-builts to track new construction projects.
- Condition collected in 2012 and 2019.
- Performing inspections with consultant funds and when one-time funding become available with a goal of meeting the 10-year target.

MANAGEMENT

- Inventory and condition data are stored in TAMS.

REPORTING

- Location, project identification and cost are reported every three years to FHWA.

NOISE WALLS ASSET VALUATION

Noise walls valuation is based on the replacement cost for the asset. Wood noise walls are replaced at $30 per square foot. Concrete noise walls are replaced at $40 per square foot.

Figure 3-20: Noise Wall Asset Valuation

WALL TYPE	COUNT	REPLACEMENT VALUE
Wood	397	$314 million
Concrete	67	$52 million
TOTAL	464	$366 million

OVERHEAD SIGN STRUCTURES

Overhead sign structures include various spans and standalone structures designed to support signs requiring vertical clearance for vehicles to pass underneath. Bridge-mounted sign structures (zero post structures) are not included in the TAMP.

Figure 3-21: Overhead Sign Inventory, 2021

Source: TAMS.

ASSET TYPE	COUNT
Overhead Sign Structures	2,104

OVERHEAD SIGNS CONDITION

Figure 3-22: Overhead Sign Condition, 2021

Source: TAMS and an external database.

ASSET TYPE	GOOD	FAIR	POOR	UNRATED
Overhead Sign Structures	24%	4.3%	14.3%	57.4%

DATA COLLECTION, MANAGEMENT AND REPORTING

DATA COLLECTION

- Condition inspections are performed in-house or via contract.
- Using standard specification for as-builts to track new construction projects.
- Inventory data is updated continually in TAMS. Condition data is updated as signs are inspected on five-year cycle.
- Data collection is managed by the Maintenance/Traffic Division.

MANAGEMENT

- Inventory and condition data are stored in TAMS.

REPORTING

- There is no official reporting of structural inspection data.

OVERHEAD SIGNS ASSET VALUATION

Replacement value for overhead signs is based on the weighted average of $125,000 per two post structure (sign bridges and cantilevers).

Figure 3-23: Overhead Sign Asset Valuation

ASSET TYPE	COUNT	REPLACEMENT VALUE
Overhead Sign Structure	2,104	$316 million

PEDESTRIAN INFRASTRUCTURE

Pedestrian assets include infrastructure that make traveling alongside or across roadways accessible to all people walking or rolling. For the TAMP, asset classes include curb ramps and sidewalks. The pedestrian infrastructure target is compliance with the federal Americans with Disability Act.

Figure 3-24: Pedestrian Infrastructure Inventory, 2021

Source: ArcGIS Database. Note: The average width of a sidewalks is 6.75 feet. MnDOT estimates that its sidewalk inventory is 698 miles in length.

ASSET TYPE	COUNT
Curb Ramp	36,608
Sidewalk	24,876,720 Sq Ft

PEDESTRIAN INFRASTRUCTURE CONDITION

Figure 3-25: Pedestrian Infrastructure Condition, 2021

Source: ArcGIS Database. Note: For ramps, ADA compliance requirements include specific geometric standards and accessible pedestrian signals. Compliance ratings are based on ADA compliance standards. Significant effort is underway to meet substantial (3% cross-slope) compliance.

ASSET TYPE	COMPLIANT	NON-COMPLIANT
Curb Ramp	61%	39%
Sidewalk	66%	34%

DATA COLLECTION, MANAGEMENT AND REPORTING

DATA COLLECTION

- MnDOT's regional districts collect inventory and condition data.
- Baseline inspections and data collection are fully updated every 10 years.

MANAGEMENT

- Data is managed in a GIS database by Operations Division staff.

REPORTING

- Internally, the ADA unit in January reports curb ramp and sidewalk compliance and percent of signals with a pedestrian phase that have accessible pedestrian signals as a MnDOT performance measure.
- Externally, the ADA unit reports three measures to the Olmstead Implementation Office to meet MnDOT's obligations for the Olmstead Plan. The three measures are number of new sidewalks added, percent curb ramp compliance and number of new Accessible Pedestrian Signals installed.

PEDESTRIAN INFRASTRUCTURE ASSET VALUATION

Pedestrian asset valuation is based on the per unit cost for replacement for each asset. Unit costs are $5,000 per curb ramp and $8 per square foot of sidewalk.

Figure 3-26: Pedestrian Infrastructure Asset Valuation

ASSET TYPE	COUNT / AREA	REPLACEMENT VALUE
Curb Ramp	36,608	$183 million
Sidewalk	24,876,720 Sq Ft	$199 million
Total	N/A	$382 million

TRAFFIC SIGNALS AND LIGHTING

Traffic signals and lighting structures are essential safety assets on the state highway system. The analysis performed in this TAMP accounts only for the structural condition; other functional and operational requirements (e.g., luminaire replacement) are not considered.

TRAFFIC SIGNALS AND LIGHTING CONDITION

Figure 3-27: Traffic Signal and Lighting Inventory, 2022

Source: TAMS.

ASSET TYPE	COUNT
Traffic Signals	1,435
Lighting Structures	28,894
Total	30,329

DATA COLLECTION, MANAGEMENT AND REPORTING

Figure 3-28: Traffic Signal and Lighting Condition, 2021

Source: TAMS. Note: Good is 0 to 12 years old, Fair is 13 to 23 years old, Poor is 24 to 29 years old, Beyond Useful Service is 30 years or more, and Unknown is traffic signals without age data.

ASSET TYPE	GOOD	FAIR	POOR	BEYOND USEFUL SERVICE LIFE	UNKNOWN
Traffic Signals	24%	29%	28%	9%	11%
Lighting Structures	51%	23%	14%	12%	N/A

DATA COLLECTION

- Inspected annually for operations, every two years for electronics, every three years for electrical and following every new install.
- 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.
- A structural inspection program is being developed but until all structures are evaluated, an age-based approach to condition ratings is being used.

MANAGEMENT

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

REPORTING

- There is no standard practice or required reports.

TRAFFIC SIGNALS AND LIGHTING ASSET VALUATION

Replacement value is based on average costs per asset. A signal system is $400,000. A light pole costs $7,500 in the Twin Cities metro area and $8,000 in Greater Minnesota. Roadway lighting units do not include walkways, underpass lighting and towers.

Figure 3-29: Traffic Signal and Lighting Asset Valuation

ASSET TYPE	COUNT	REPLACEMENT VALUE
Traffic Signals	1,435	$574 million
Lighting Structures	28,894	$221 million
Total	30,329	$795 million

HIGH-MAST LIGHT TOWERS

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

HIGH-MAST LIGHT TOWER CONDITION

Figure 3-30: High-Mast Light Tower Inventory, 2021

Source: TAMS.

ASSET TYPE	COUNT
High-Mast Light Tower	482

Figure 3-31: High-Mast Light Tower Structural Condition, 2021

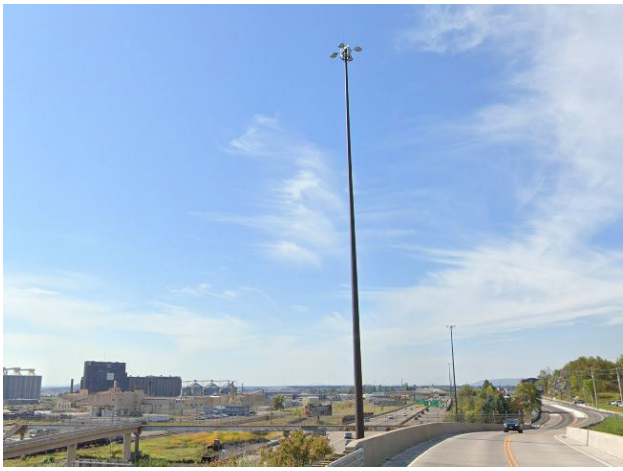
Source: TAMS.

ASSET TYPE	GOOD	FAIR	POOR
High-Mast Light Tower	78%	13%	8%

DATA COLLECTION, MANAGEMENT AND REPORTING

DATA COLLECTION

- Condition inspections are performed in-house or via contract.
- Data collection is typically on a five-year cycle.
- Data collection is managed by the Bridge Office.



MANAGEMENT

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

REPORTING

- There is no official reporting of structural inspection data.

HIGH-MAST LIGHT TOWER ASSET VALUATION

Replacement Value for high-mast light towers is based on an average cost $40,000 per structure.

Figure 3-32: High-Mast Tower Asset Valuation

ASSET TYPE	COUNT	REPLACEMENT VALUE
High-Mast Light Tower	482	$19.3 million

NON-STATE OWNERS OF THE NHS

As part of the TAMP process, MnDOT met with local owners of the NHS. Figures 3-34 and 3-35 display NHS pavement segments and bridges owned by locals and include route information, owner name, length and bridge number where applicable.

Figure 3-33: Non-State Owned NHS Pavement Segments, 1 of 2

OWNER	ROUTE	STREET NAME	CENTERLINE MILES
Anoka County	CSAH 23	Lake Dr	1.4
Anoka County	CSAH 14	Main St/125th Ave	11.8
Dakota County	CSAH 23	Cedar Ave	1.3
Dakota County	CSAH 32	Cliff Rd	2.1
Dakota County	CSAH 42	145th St E/145th St W/150th St W	17.4
City of Duluth	MSAS 137	S 3rd Ave	0.0
City of Duluth	MSAS 138	S 2nd Ave	0.0
City of Duluth	MSAS 140	N Lake Ave	0.1
City of Duluth	MSAS 145	W Michigan St	0.1
City of Duluth	MSAS 149	Garfield Ave	0.9
City of Duluth	MSAS 171	W Superior St	0.7
City of Duluth	MSAS 200	Helberg Dr	0.7
City of Duluth	N/A	Port Terminal Dr	0.5
City of Duluth	N/A	Garfield Ave	0.2
City of Duluth	N/A	Garfield Ave	0.4
City of East Grand Forks	MSAS 120	Central Ave/Demers Ave	0.5
Hennepin County	CSAH 81	Main St	0.1
Hennepin County	CSAH 152	Cedar Ave S/Washington Ave N	0.4
Hennepin County	CSAH 153	Lowry Ave N	0.9

Figure 3-33: Non-State Owned NHS Pavement Segments, 2 of 2

OWNER	ROUTE	STREET NAME	CENTERLINE MILES
Metropolitan Airports Commission	N/A	Glumack Dr – Upper Level	1.7
Metropolitan Airports Commission	N/A	Glumack Dr – Lower Level	0.5
City of Minneapolis	MSAS 169	Dowling Ave N	0.0
City of Minneapolis	MSAS 215	2nd St N	0.6
City of Minneapolis	N/A	32nd Ave NE	0.1
City of Minneapolis	N/A	30th Ave NE	0.1
City of Minneapolis	N/A	E Frontage Rd	0.2
Minnesota Army National Guard (Camp Ripley)	N/A	Infantry Rd	1.7
Ramsey County	CSAH 36	Warner Rd	2.4
Ramsey County	CSAH 37	Shepard Rd	2.2
City of Rochester	MSAS 201	S Broadway Ave	0.1
Saint Louis County	CSAH 91	Haines Rd	1.5
City of Saint Paul	MSAS 194	W Shepard Rd	0.9
City of Saint Paul	MSAS 249	W Shepard Rd	0.8
Scott County	CSAH 21	Crest Ave/Eagle Creek Ave	3.6
Scott County	CSAH 42	140th St/Egan Dr	5.5
Stearns County	CSAH 75	Division St/Roosevelt Rd	13.8
City of Willmar	MSAS 153	1st St NE	4.6

Figure 3-34: Non-State Owned NHS Bridges, 1 of 2

BRIDGE NUMBER	OWNER	INSPECTING AGENCY	LOCATION
36002	Aazhogan/BMI Group (Operator)	Aazhogan/BMI Group	US 53 NB/SB autos; NB trucks over Rainy River
90249	Aazhogan/BMI Group (Operator)	Aazhogan/BMI Group	US 53 SB; MDW RR over Rainy River
02583	Anoka County	Anoka County	Main St NW over BNSF RR
02015	Anoka County	Anoka County	Main St NW over Coon Creek; weak soil
02577	Anoka County	Anoka County	Main St NW over ditch
02J45	Anoka County	Anoka County	Main St NW over ped trail
27X17	City of Champlin	Metro District	US 169 over ped trail.
93346	Cleveland-Cliffs Inc (Mining)	District 1	MN 61 over conveyor tunnel
19560	Dakota County	Dakota County	CSAH 42 over CP RR
69J51	City of Duluth	City of Duluth	W Superior St over pedestrian underpass

Figure 3-34: Non-State Owned NHS Bridges, 2 of 2

BRIDGE NUMBER	OWNER	INSPECTING AGENCY	LOCATION
66X03	City of Faribault	District 6	MN 3 over TH 3 trail
27B60	Hennepin County	Hennepin County	CSAH 153 over Mississippi; CP RR
R0834	Metropolitan Airports Commission	Metropolitan Airports Commission	Upper-level roadway over Terminal Road #1
42X06	City of Marshall	District 8	MN 23 over ped trail
73X01	Martin Marietta (Mining)	District 3	MN 23 over quarry road
27X10	City of Minneapolis	Metro District	I 35W over ped trail
34X05	Department of Natural Resources	District 8	US 71 over ped trail
62531	Ramsey County	City of Saint Paul	WB Warner Rd over railroads; Childs Rd
62634	Ramsey County	City of Saint Paul	CSAH 36 (Warner Rd) over railroads and streets
62597	Ramsey County	City of Saint Paul	Shepard Rd (CSAH 37) over sewer
62560	Ramsey County	City of Saint Paul	Shepard Rd over UP RR.
69K18	Saint Louis County	Saint Louis County	Haines Rd over Millers Creek
91675	Saint Louis County	Saint Louis County	Haines Rd over Millers Creek
62513	City of Saint Paul	City of Saint Paul	W Shepard Rd over Texaco oil
62512	City of Saint Paul	City of Saint Paul	EB W Shepard Rd over Koch oil
62512A	City of Saint Paul	City of Saint Paul	WB W Shepard Rd over Koch oil
5830A	City of Savage	City of Savage	MUN 101 frontage over Eagle Creek
70J45	Scott County	Scott County	CSAH 21 over Ped-Bike underpass
70J46	Scott County	Scott County	CSAH 21 over Ped-Bike underpass
70J44	Scott County	Scott County	CSAH 21 over UNNAMED
97210	Scott County	Scott County	Egan Dr over Credit River
8432	Stearns County	Stearns County	CSAH 75 over stream
73552	Stearns County	Stearns County	CSAH 75 over BNSF RR
6819	Stearns County	Stearns County	CSAH 75 over Sauk River
34524	City of Willmar	City of Willmar	MSAS 153 over BNSF RR; US 12; streets
95061	City of Willmar	City of Willmar	1ST St S over county ditch #23; BR #2

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ASSET MANAGEMENT PERFORMANCE MEASURES, TARGETS AND PERFORMANCE GAPS

Since the mid-1990s, the Minnesota Department of Transportation has used performance measures to assess system performance and inform investment priorities and operational strategies. In 2003, MnDOT adopted the first performance-based statewide transportation plan in the nation. MnDOT maintains both state measures and federal measures. For the state measures, MnDOT sets performance targets that represent the desired condition. Targets are a valuable tool for highlighting system performance, risk and investment decision making. This chapter presents each asset's performance measure, target and performance gap.

On July 6, 2012, the Moving Ahead for Progress in the 21st Century Act was signed. MAP-21 required states to develop a risk-based Transportation Asset Management Plan for the National Highway System to improve and preserve the condition of the assets and the system's performance. A key feature of MAP-21 was the establishment of pavement and bridge performance measures and targets for the NHS. These federal measures do not match MnDOT's state measures. Moreover, the federal targets are set for two and four-year outcomes, whereas MnDOT targets apply regardless of year. This chapter shows the state targets for pavement and bridges and required federal targets. The 10 remaining asset classes do not have federal targets but do have state targets.

TARGET TERMINOLOGY IN THE TAMP

The following terms differentiate state and federal targets as well as performance gaps.

State Targets are specific values against which MnDOT evaluates past, present and future performance. They represent the achievement of a goal, outcome or objective. 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. MnDOT uses state targets as long-term targets.

Federal Targets refer to the required two and four year targets for NHS pavements and bridges submitted to the Federal Highway Administration to report on federal performance measures. State DOTs must set the targets in coordination with Metropolitan Planning Organizations. These targets are not MnDOT's desired outcomes but are the expected outcome for the asset condition in two and four years based on projects in the existing program.

Performance Gap is the difference between projected performance and the asset's target. For the TAMP, the performance gap is calculated for the next 10 years.

PAVEMENT PERFORMANCE MEASURES

The state performance measures for pavements are the share of system lane miles with good ride quality and the share of lane miles with poor ride quality. Ride quality is assessed using MnDOT's Ride Quality Index, which measures pavement smoothness as perceived by the typical driver. Pavement rated poor can still be driven on, but the ride is rough enough at 50 miles per hour or greater that most people would find it uncomfortable and decrease their speed.

The federal pavement performance measure includes roughness, rutting/faulting and cracking calculations, and is limited to the NHS. A segment of pavement is poor if two out of three measures are poor. A segment is good if all three measures are good.

STATE PAVEMENT TARGETS

Figure 4-1: Pavement State Targets

SYSTEM	PERCENT RQI GOOD	PERCENT RQI POOR
Interstate NHS	70%	2%
Non-Interstate NHS	65%	4%
Non-NHS	60%	8%

MnDOT has separate performance targets for the Interstate, non-Interstate NHS and non-NHS. The MnDOT targets are shown in Figure 4-1. The condition levels represent a performance standard consistent with traveler expectations.

Between adopting the 2019 TAMP and this 2022 TAMP, MnDOT pavement staff recommended that the target for non-NHS pavement move from no more than 10% poor to no more than 8% poor. The recommendation aligns with historic highs on the non-NHS. Approaching 8% poor, MnDOT has pushed for additional revenue to decrease the poor condition, representing a level the agency does not want to cross. Additionally, the recommendation aligns with the non-NHS bridge target, which is also no more than 8% poor.

FEDERAL PAVEMENT TARGETS

For the 2022-2025 performance period, MnDOT used a combination of internal workgroup target identification and MPO coordination and feedback to select targets for pavement condition on the NHS.

Figure 4-2 shows Minnesota's federal pavement targets, as reported in the 2022 Baseline Performance Period Report due in the fall 2022.

Figure 4-2: Pavement Federal Targets

SYSTEM	2023 TARGET GOOD CONDITION	2023 TARGET POOR CONDITION	2025TARGET GOOD CONDITION	2025 TARGET POOR CONDITION
Interstate	60%	2%	60%	2%
Non-Interstate NHS	55%	2%	55%	2%

PAVEMENT PERFORMANCE GAPS

Federal targets are set based on anticipated outcomes from programmed projects in the STIP. Because of this, there are no anticipated performance gaps to meet the federal targets for pavement.

The planned investment for Interstate and Non-Interstate NHS pavements are sufficient to meet state targets in the next 10 years. Non-NHS will not meet the target in 10 years. An additional $1.3 billion is necessary to meet the non-NHS target.

MnDOT is currently updating its 20-year State Highway Investment Plan, which sets the capital investment direction for the state. That process will provide an opportunity to adjust the amount of money directed towards pavement investments and may change the funding gap to meet targets.

Figure 4-3: Pavement Performance Gaps for State Measures and Targets

SYSTEM	CURRENT CONDITION (2021)	PROJECTED CONDITION IN 2032	STATE TARGETS	PLANNED INVESTMENT	ADDITIONAL INVESTMENT NEEDED TO REACH TARGETS
Interstate	92.5% Good, 0.4% Poor	88.7% Good, 1.3% Poor	70% Good, 2% Poor	$1 billion	$0
Non-Interstate NHS	82.2% Good, 0.5% Poor	81.5% Good, 3.9% Poor	65% Good, 4% Poor	$2.4 billion	$0
Non-NHS	77.2% Good, 2.4% Poor	58% Good, 14.6% Poor	60% Good, 8% Poor	$1.4 billion	$1.3 billion
Total	N/A	N/A	N/A	$4.8 billion	$1.3 billion

BRIDGE PERFORMANCE MEASURES

The state and federal performance measure is the share of system bridges in good and poor condition as a percent of the total bridge deck area. Bridge condition is calculated from inspections on all state highway bridges. The rating combines deck, superstructure and substructure evaluations. MnDOT's state measure for bridges considers all structures with spans of 10 feet or greater. The federal bridge measure is limited to bridges with spans of 20 feet or greater.

STATE BRIDGE TARGETS

MnDOT has separate performance targets for NHS and non-NHS bridges. The targets are shown in Figure 4-4. NHS bridge poor condition target changed from 2% poor to no more than 5% poor between 2019 and this TAMP. The 2019 approach resulted in fewer preservation and rehabilitation projects. The change supports an asset management strategy that includes an array of treatments and puts more resources towards keeping good conditions good. 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.

Figure 4-4: State Bridge Targets (spans greater than 10 feet)

SYSTEM	PERCENT GOOD	PERCENT POOR
NHS	55%	5%
Non-NHS	50%	8%

FEDERAL BRIDGE TARGETS

For the 2022-2025 performance period, MnDOT used a combination of internal workgroup target identification and MPO coordination and feedback to select targets for federal bridge measures on the NHS.

Figure 4-5 shows Minnesota's federal bridge targets, as reported in the 2022 Baseline Performance Period Report, due in the fall of 2022.

BRIDGE PERFORMANCE GAPS

Figure 4-5: Federal Bridge Targets (spans greater than 20 feet)

SYSTEM	2023 TARGET GOOD CONDITION	2023 TARGET POOR CONDITION	2025 TARGET GOOD CONDITION	2025 TARGET POOR CONDITION
NHS	30%	5%	35%	5%

Federal targets are set based on anticipated outcomes from programmed projects in the STIP. Because of this, there are no anticipated performance gaps to meet the federal targets for bridge.

In the next 10 years, the planned investment for NHS and Non-NHS bridges is insufficient to meet state targets. MnDOT projects that bridges will need an additional $2.2 billion to reach the targets in 10 years. The planned investment shown here does not include any increased funding for bridge condition authorized by the Infrastructure Investment and Jobs Act, which MnDOT has not yet programmed. That additional funding should improve projected conditions and thus reduce the additional funding necessary to reach targets in 10 years.

MnDOT is currently updating its 20-year State Highway Investment Plan, which sets the capital investment direction for the state. That process will provide an opportunity to adjust the amount of money directed towards bridge investments and may change the funding gap to meet targets.

Figure 4-6: Bridge Performance Gaps for State Measure and Targets

SYSTEM	CURRENT CONDITION (2020)	PROJECTED CONDITION IN 2032	STATE TARGETS	PLANNED INVESTMENT	ADDITIONAL INVESTMENT NEEDED TO REACH TARGETS
NHS	32.9% Good 3.1% Poor	36.1% Good 10.4% Poor	50% Good 5% Poor	$843 million	$1.4 billion
Non-NHS	32.6% Good 3.8% Poor	29.3% Good 12.4% Poor	50% Good 8% Poor	$496 million	$845 million
Total	N/A	N/A	N/A	$1.3 billion	$2.2 billion

ALL OTHER ASSETS

There are no federal requirements for condition targets for the other assets included in the TAMP. However, as part of the TAMP process, MnDOT developed state performance measures and targets for each asset.

BUILDINGS PERFORMANCE MEASURES

MnDOT's performance measure for buildings is the share in poor condition. Building condition is assigned by the Office of Maintenance Building Services Section once every three years. The Facilities Condition Index scores buildings from excellent to poor. The FCI is calculated as the ratio of deferred maintenance to the current replacement value of the facility. The smaller the FCI, the better the condition.

MnDOT does not use a unified target-setting methodology for building assets. All nine building types have different target-setting methods. However, all targets are set through asset expert discussion and cross-asset analysis.

Buildings that deliver essential services such as rest areas and office buildings have aggressive targets to prevent assets from entering poor condition. On the other hand, structures that are non-habitable, like salt shelters and unheated sheds, have less aggressive targets.

Figure 4-7: Building Targets

BUILDING TYPE	TARGET POOR CONDITION
Rest Area	4%
Weigh Station	15%
Truck Station (Class 2/3) – Small Truck Storage	5%
Truck Station (Class 1)	3%
Salt Shelter	15%
Office Facility	0%
Heated Shed	10%
Unheated Shed	10%

BUILDINGS PERFORMANCE GAPS

At present, MnDOT's buildings portfolio is generally in good condition. However, the 20-Year Strategic Facilities Asset Management Plan completed in 2021 found that the facilities will not maintain a condition level of "Good" or better (i.e., an FCI of 0.15 or less) if funding for planned repair and replacement is less than approximately $33 million per year. The current funding level is $13 million, leaving an annual funding gap of $20 million.

HIGHWAY CULVERTS AND DEEP STORMWATER TUNNELS PERFORMANCE MEASURES

MnDOT's performance measure for culverts is the share in poor condition. For deep stormwater tunnels, MnDOT's performance measure is also the share in poor condition (measured as a percent of total tunnel system length).

Highway culvert condition is assigned during inspections. Culverts in poor condition display characteristics including separation of joints or holes which could cause soils loss under a road. This could result in damage to the roadway itself, including collapse.

Deep stormwater tunnel condition is assigned during inspections. Inspections identify and measure cracks, fractures and voids behind the tunnel liners. Tunnels in poor condition with a rating of four have significant cracks and voids behind the unreinforced tunnel liner. Tunnels with a condition rating of five have defects that require timely corrective action.

The targets for culverts and deep stormwater tunnels are unchanged for the 2022 TAMP. Asset experts established the targets as part of the 2019 TAMP. The deep stormwater tunnel target matches highway culverts.

Figure 4-8: Highway Culverts and Deep Stormwater Tunnel Targets

ASSET TYPE	TARGET POOR CONDITION
Highway Culverts	10%
Deep Stormwater Tunnel	10%

HIGHWAY CULVERTS AND DEEP STORMWATER TUNNELS PERFORMANCE GAPS

The planned investment for highway culverts is not projected to meet the target in the next 10 years. MnDOT estimates that, given current conditions, highway culverts will need an additional $69 million over the next decade to reach the target. Deep stormwater tunnels are projected to be sufficiently funded to achieve and maintain their target over the next 10 years. The performance gap is determined using the life cycle planning tool in **Chapter 6: Life Cycle Planning**.

Figure 4-9: Highway Culverts and Deep Stormwater Tunnel Performance Gap

ASSET TYPE	CURRENT POOR CONDITION (2020)	PROJECTED POOR CONDITION IN 2032	TARGET POOR CONDITION	PLANNED INVESTMENT	ADDITIONAL INVESTMENT NEEDED TO REACH TARGETS
Highway Culverts	18%	23%	10%	$258 million	$69 million
Deep Stormwater Tunnels	0%	1%	10%	$7 million	$0

INTELLIGENT TRANSPORTATION SYSTEMS PERFORMANCE MEASURES

MnDOT's performance measures for ITS are the share of each sub-asset approaching or beyond their useful life. ITS asset condition is continuously monitored as they provide data on the operation of the state highway system.

Figure 4-10: Intelligent Transportation Systems Targets

ITS SUB ASSET TYPE	TARGET (APPROACHING OR BEYOND USEFUL SERVICE LIFE)
Fiber Communication Network Miles	4%
Fiber Network Shelters	5%
Traffic Management System Cabinet	7%
Dynamic Message Signs	7%
Traffic Monitoring Cameras	5%
Traffic Detector Stations/Site -Loops and Radar	2%
E-ZPASS Readers	2%
Reversible Road Gates	0%
Ramp Meters	0%
Road Weather Information Systems	2%
Road Weather Information Systems Sites	2%
Automatic Traffic Recorders Sensors	10%
Weigh-In-Motion System Sites Sensors	10%

When setting the target, the asset workgroup considered at what age the asset can still function but is no longer cost-effective to maintain. This is deemed the asset's useful life. This is because technological advancement will make most technology obsolete eventually, despite maintenance. For setting targets, MnDOT considered public safety and seasonal factors. For example, intersection warning systems that break down are dangerous to the traveling public. Also, some assets cannot be maintained in the winter months, leading to a more rapid decline in condition.

INTELLIGENT TRANSPORTATION SYSTEMS PERFORMANCE GAPS

In the next 10 years, the planned investment for ITS is projected to be insufficient for most sub-asset types. Figure 4-11 displays the planned investments and performance gaps for ITS assets. The performance gap is determined using the life cycle planning tool in **Chapter 6: Life Cycle Planning**.

Figure 4-11: Intelligent Transportation Systems Performance Gap

Note: A portion of $15 million planned investment is from Regional Traffic Monitoring Center budget, the $2.6 million is from Transportation Data and Analysis Section budget, and the $2 million is from the Road Weather Technology budget. The planned investment shown here does not account for one time funding or leftover end of year funding used to address ITS needs.

ITS SUB ASSET TYPE	CURRENT CONDITION (2020)	PROJECTED CONDITION IN 2032	TARGET	PLANNED INVESTMENT	ADDITIONAL INVESTMENT NEEDED TO REACH TARGETS
Fiber Communication Network Miles	17.2%	53.9%	4%	A portion of $15 million*	$76.4 million
Fiber Network Shelters	1.1%	27%	5%	A portion of $15 million	$14 million
Traffic Management System Cabinet	1.9%	11%	7%	A portion of $15 million	$21.5 million
Dynamic Message Signs	12.2%	18%	7%	A portion of $15 million	$53.6 million
Traffic Monitoring Cameras	0%	12%	5%	A portion of $15 million	$6.6 million
Traffic Detector Stations/Site -Loops and Radar	39%	19%	2%	A portion of $15 million	$30.3 million
E-ZPASS Readers	0%	18%	2%	A portion of $15 million	$1.8 million
Reversible Road Gates	0%	0%	0%	A portion of $15 million	$0.2 million
Ramp Meters	0%	18%	2%	A portion of $15 million	$4.8 million
Road Weather Information Systems Sites	0%	15%	2%	$2 million	$11.4 million
Automatic Traffic Recorders Sensors	0%	32%	10%	A portion of $2.6 million	$12.6 million
Weigh-In-Motion System Sites Sensors	0%	26%	10%	A portion of $2.6 million	$8.3 million

NOISE WALLS PERFORMANCE MEASURE

MnDOT's performance measure for noise walls is the share in poor condition. The condition ratings are based on an inspector evaluation of the above ground portion of the wall. This evaluation is the Element Condition Score Index. It incorporates both a subjective rating and a scoring formula by structural element conditions. The condition assessment is currently collected in a 1 to 4 scale but is transitioning to a 1 to 9 overall condition score with a 1 to 4 element condition scale.

The noise wall target of 8% poor is based on accepted risk. Above 8%, the likelihood and the consequences of a structure failing is too high a risk. Risk is dependent on wall location as some walls may fall into private property, other structures, or frontage roads if they fail.

NOISE WALLS PERFORMANCE GAPS

In the next 10 years, the planned investment for noise walls is projected to be sufficient to meet and maintain the target. The performance gap is determined using the life cycle planning tool in **Chapter 6: Life Cycle Planning**.

Figure 4-12: Noise Walls Performance Gap

ASSET TYPE	CURRENT POOR CONDITION (2021)	PROJECTED POOR CONDITION IN 2032	TARGET POOR CONDITION	PLANNED INVESTMENT	ADDITIONAL INVESTMENT NEEDED TO REACH TARGETS
Noise Walls	6%	6.7%	8%	$40 million	$0

OVERHEAD SIGNS PERFORMANCE MEASURE

MnDOT's performance measure for overhead sign structures is the share of 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 other defects.

The overhead sign structures target of 6% poor is based on accepted risk. Above 6%, the likelihood of a structure failing is too high of a risk. MnDOT expects the share of overhead sign structures in poor condition to decline in the future as installation specifications, protocols and responsible internal workplans are applied.

OVERHEAD SIGNS PERFORMANCE GAPS

In the next decade, MnDOT's planned investment for overhead signs is projected to be insufficient to meet the target. Given current conditions, overhead signs will need an additional $5 million over the next 10 years to reach the target. The performance gap is determined using the life cycle planning tool in **Chapter 6: Life Cycle Planning**.

Figure 4-13: Overhead Signs Performance Gap

Note: As of 2021, only 43% of the inventory was inspected. Of those inspected, 33.6% were in poor condition.

ASSET TYPE	CURRENT POOR CONDITION (2021)	PROJECTED POOR CONDITION IN 2032	TARGET POOR CONDITION	PLANNED INVESTMENT	ADDITIONAL INVESTMENT NEEDED TO REACH TARGETS
Overhead Signs	34%	12%	6%	$28 million	$5 million

PEDESTRIAN INFRASTRUCTURE PERFORMANCE MEASURE

MnDOT's performance measures for pedestrian infrastructure are the share of curb ramps and sidewalk miles that are non-compliant with the Americans with Disabilities Act. After construction, compliance is documented. If there are any data gaps, MnDOT will send staff a year after to inspect condition. MnDOT then assesses conditions every 10 years.

Targets are set to achieve and maintain ADA compliance. The targets are not 100% compliance because sidewalks on steep slopes, ongoing deterioration and existing infrastructure throughout the state prevent MnDOT from reaching that threshold.

Figure 4-14: Pedestrian Infrastructure Targets

ASSET TYPE	PERCENT NON-COMPLIANT	PERCENT COMPLIANT
Curb Ramps	6%	94%
Sidewalks	5%	95%

PEDESTRIAN INFRASTRUCTURE PERFORMANCE GAPS

In the next 10 years, the planned investment for pedestrian infrastructure is projected to be insufficient to meet targets. Given current conditions, MnDOT projects curb ramps will need an additional $86 million, and sidewalks will need an additional $143 million over the next 10 years to reach the targets. The performance gap is determined using the life cycle planning tool in **Chapter 6: Life Cycle Planning**.

Figure 4-15: Pedestrian Infrastructure Performance Gaps

ASSET TYPE	CURRENT NON-COMPLIANT CONDITION (2021)	PROJECTED NON-COMPLIANT CONDITION IN 2032	TARGET NON-COMPLIANT CONDITION	PLANNED INVESTMENT	ADDITIONAL INVESTMENT NEEDED TO REACH TARGETS
Curb Ramps	39%	18%	6%	$158 million	$86 million
Sidewalks	34%	31%	5%	$109 million	$143 million

TRAFFIC SIGNALS AND LIGHTING PERFORMANCE MEASURE

MnDOT's performance measures for signals and lighting are the share of structures beyond useful life.

An age-based approach is used for signals and lighting. When setting the target, the asset workgroup considered at what age the asset can still function but is no longer cost-effective to maintain due to poles becoming structurally deficient. This is deemed the asset's useful life. The useful life for both signals and lighting are 30 years. The targets for traffic signal systems and lighting are both no greater than 2% beyond useful service life.

TRAFFIC SIGNALS AND LIGHTING PERFORMANCE GAPS

In the next 10 years, MnDOT's planned investment for signals and lighting is projected to be insufficient to meet targets. Given current conditions, signals will need an additional $387 million, and lighting will need an additional $100 million over the next 10 years to reach the targets. The performance gap is determined using the life cycle planning tool in **Chapter 6: Life Cycle Planning**.

Figure 4-16: Traffic Signal and Lighting Performance Gaps

ASSET TYPE	CURRENT CONDITION (2021)	PROJECTED CONDITION IN 2032	TARGET BEYOND USEFUL SERVICE LIFE	PLANNED INVESTMENT	ADDITIONAL INVESTMENT NEEDED TO REACH TARGETS
Traffic Signal	9%	44%	2%	$162 million	$387 million
Lighting	12%	37%	2%	$126 million	$100 million

HIGH-MAST LIGHT TOWER PERFORMANCE MEASURE

MnDOT's performance measure for high-mast light towers is the share of towers in poor condition. This includes towers rated poor and towers that are beyond a useful service life. The Bridge Office assesses high-mast light tower conditions on a five-year cycle. The assessment inspects the structure LED luminaires, tightens the nuts, and conducts general maintenance.

In 2014, the asset expert workgroup developed and recommended a performance target of no more than 6% poor for high-mast light towers. Above 6%, the likelihood of a structure failing is too high of a risk.

HIGH-MAST LIGHT TOWER PERFORMANCE GAP

Figure 4-17: High-Mast Light Tower Performance Gap

Note: Poor is a combination of percent of high-mast light towers in poor condition and beyond useful service life.

ASSET TYPE	CURRENT POOR CONDITION (2021)	PROJECTED POOR CONDITION IN 2032	TARGET POOR CONDITION	PLANNED INVESTMENT	ADDITIONAL INVESTMENT NEEDED TO REACH TARGETS
High-Mast Light Towers	8%	8%	6%	$4 million	$1 million

In the next 10 years, the planned investment for high-mast light towers is projected to be short of the target by $1 million. The performance gap is determined using the life cycle planning tool in **Chapter 6: Life Cycle Planning**.

RISK MANAGEMENT

Risk is frequently defined as the effect of uncertainty or variability on objectives. When applied to transportation assets, understanding risk helps transportation agencies effectively plan for system disruptions, mitigate potential consequences, improve the agency and build resilience. The Minnesota Department of Transportation's Enterprise Risk Management Framework considers risk across the organization. The organization's leadership team identifies significant risks to MnDOT's strategy and then seeks to actively manage or reduce those risks across agency functions.

Risk management is integrated into most agency planning and management practices. MnDOT's strong history of risk management compelled the agency to customize an approach to risk management in the Transportation Asset Management Plan, described in the TAMP Risk Assessment section of this chapter.

Throughout this chapter, there are various risk-related terms. A complete glossary of these terms and others is included in Appendix A.

RISK AT MNDOT

MnDOT has adopted risk management principles throughout the agency, from high-level investments, management, operations plans, individual asset management, programming systems and research projects.

To categorize risk, MnDOT implemented the Enterprise Risk Management Framework. The framework illustrated in Figure 5-1 establishes the standards, processes and accountability structure used to identify, assess, prioritize and manage critical risk exposures across the agency. Creating risk tiers enable leaders and agency staff to consider the implications of risk, make informed decisions and know who is responsible for monitoring the risks.

Figure 5-1: Levels of Risk Management at MnDOT

RISK LEVEL	SUMMARY
Enterprise	Risks to the organization's strategic objectives or risks that involve multiple levels. The responsibility of Executive and Senior Leadership Teams acting in their capital, governance and operating council roles.
Program / Product and Services	Risks that are common to groups of projects that achieve strategic objectives. The responsibility of Management groups in coordination with Assistant Commissioners.
Project / Activity	Risks that are specific to individual projects and ongoing functions. The responsibility of Office Directors, Office Managers, and Staff.

CAPITAL PLANNING RISK MANAGEMENT

Risk was a key factor considered during the development of the 2018-2037 Minnesota State Highway Investment Plan. During the planning process, MnDOT systematically identified the likelihood and impact of different risks to assess the trade-offs associated with various investment levels across all assets. The document guides MnDOT's future investment planning. The plan is currently being updated and the new plan will be complete in 2023. The TAMP risk process will inform the identification of capital investment risks in the new MnSHIP.

OPERATIONAL RISK MANAGEMENT

In addition to capital program risk management, MnDOT has made great strides in reducing risks for operations and maintenance. MnDOT has made focused investments to inventory ancillary assets, such as culverts, traffic barriers and signs. Developing data for these assets allows MnDOT to make risk-based performance measures for maintenance work. For example, response time to a sign hit is based on sign type.

Operations and maintenance performance measures have been developed to reduce the likelihood of asset failure and prioritize preventive maintenance and inspections to optimize asset life. Inspections are frequently the most cost-effective means of mitigating risk. Simply knowing what MnDOT owns and keeping tabs on its condition pays dividends. An example of this is the bridge culvert inspection protocol. The system is risk-based, meaning that inspection frequency increases as the condition declines.

Under development is a new set of tools in TAMS that will marry performance measure metrics, inspection recommendations and historical maintenance needs to display work demand. The work demand will be used to make risk-based decisions for annual work planning.

RESILIENCE AND RISK IN THE TAMP

Federal regulation requires the TAMP to include planning for extreme weather and resilience. MnDOT considers extreme weather and resilience at the enterprise, program and project level. FHWA generally defines resilience as “the ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions.”

In the TAMP, extreme weather and asset resilience are considered for each asset class. Where applicable, the asset workgroups identified the risk to the asset and determined an ideal mitigation strategy. For instance, a risk to pavement assets is “significant damage to the asset through man-made or natural events.” The corresponding mitigation strategies are an array of actions that include:

- Identify potential needs in scoping (climate models, slope vulnerability analysis, emergency response history, etc.).
- Identify a separate pot of money that may be used to address reactive needs.
- Better study these events and learn more about how to mitigate them.
- Study more resilient designs.

For additional risks associated with extreme weather and asset resilience, see Figures 5-3 – 5-11 under the Risk Management Category: Infrastructure Resilience.

TAMP RISK ASSESSMENT

Risk management is an integral part of MnDOT's planning practices. The TAMP risk assessment started with considering MnDOT's enterprise risks. The TAMP Advisory group determined which enterprise risks were directly related to asset management and identified additional key risks that limited MnDOT's ability to reach the agency's asset management vision.

With the enterprise risks related to asset management identified, asset workgroups wrote risk statements for key asset-specific risks. For example, the pavement workgroup wrote "the inability to manage to the lowest life cycle cost," which relates to the enterprise risk of insufficient funding. With these risk statements, the workgroups identified current mitigation strategies to manage the risk, gaps in current business practices that may limit MnDOT's ability to control the risk and rated the risk on the likelihood and impact of a risk occurring. As an example, for the pavement risk of an "inability to manage to the lowest life cycle cost," the workgroup rated both the likelihood and the impact of the risk occurring as high.

The next step in the TAMP risk assessment was to define ideal mitigation strategies for each risk statement. Clearly defined actions help identify the data, resources, tools, training and approximate cost needed to implement. The workgroups rated the ideal mitigation strategies on their potential to change the likelihood and impact of the risk occurring. A change in rating did not always occur. A change relies on a variety of factors for each risk. In some instances, the ideal mitigation is effective enough to mitigate the risk entirely. In those cases, the rating is labeled as 'Mitigate Risk.'

In the 2019 TAMP, the risk identification process led MnDOT to emphasize "undermanaged risks," which are risks with clear improvement opportunities. The 2022 TAMP risk assessment made several adjustments to the 2019 approach. Enterprise risks and asset management risks were clearly identified, evaluated and integrated into the communications and monitoring process for the TAMP. Connecting asset management risks to broader risks in the organization has helped provide the necessary structure and empower the organization's leadership to see their role in improving asset management at MnDOT. Figures 5-3 – 5-11 display risks, ideal mitigation strategies and risk ratings for each asset included in the TAMP.

Figure 5-2: Risk Rating Matrix

Likelihood	Very Low (Insignificant)	Low (Minor)	Medium (Moderate)	High (Major)	Very High (Catastrophic)
Very High (>1x/Year)	Medium	Medium	High	Very High	Ultra High
High (~1x/Year)	Medium	Medium	Medium	High	Very High
Medium (1x/3 Years)	Low	Medium	Medium	High	High
Low (1x/10 Years)	Very Low	Low	Medium	Medium	High
Very Low (<1x/10 Years)	Very Low	Very Low	Low	Medium	Medium

Impact

RISK, IDEAL MITIGATION STRATEGIES AND RATING BY ASSET TYPE

Figure 5-3: Pavement Risks, Ideal Mitigation Strategy and Rating, 1 of 2

RISK CODE	RISK CATEGORY	RISK	IDEAL MITIGATION STRATEGY	CURRENT RISK RATING	POST MITIGATION RISK RATING
1P	Aging Infrastructure	Premature deterioration of pavements (e.g., construction issues, increase in traffic, higher equivalent single axle loads (ESALs) and snow and ice removal methods)	Better training for construction inspectors. Change design (or over-design) according to better projections (e.g., VMT, HCVMT, ESALs, environmental factors)	High	High
2P	Funding	Inability to manage to the lowest life cycle cost	Use various tools to communicate the need/benefit of following the lowest LCP strategy by implementing a regular pavement management schedule	High	High
3P	Funding	Significant reduction in funding over time	Identify alternative revenue sources due to reductions from various sources resulting from technological changes. Continue to research how to optimize MnDOT's dollars	High	High

Figure 5-3: Pavement Risks, Ideal Mitigation Strategy and Rating, 2 of 2

RISK CODE	RISK CATEGORY	RISK	IDEAL MITIGATION STRATEGY	CURRENT RISK RATING	POST MITIGATION RISK RATING
4P	Data Management/ Lack of Data/ Quality of Data	Low prioritization of ancillary pavements (e.g., frontage roads, ramps, auxiliary lanes and rest areas)	Study cost-benefit of treating ancillary pavements as separate assets independent of mainline using different measures, deterioration modeling and data collection	Medium	Medium
5P	Infrastructure Resilience	Significant damage to the asset through human-made or natural events	Include potential needs in scoping (climate models, slope vulnerability analysis, emergency response history, etc.). Identify a separate pot of money to address reactive needs. Better study these events and learn how to mitigate them. Study more resilient designs.	Medium	Medium
6P	Succession Planning	Losing construction experience through attrition	Create a vocational program for highway technicians. Improve tech certification program by working with industry to improve outreach	Medium	Medium
7P	Competing Stakeholder Expectations	Not meeting public expectations for pavement quality/condition (state, district and local levels)	Educate the public on what it takes to maintain the roads (e.g., surface rating vs. the structure itself, what it takes to maintain roads and what jurisdiction is responsible)	Medium	Medium

Figure 5-4: Bridge Risks, Ideal Mitigation Strategy and Rating, 1 of 2

RISK CODE	RISK CATEGORY	RISK	IDEAL MITIGATION STRATEGY	CURRENT RISK RATING	POST MITIGATION RISK RATING
1B	Aging Infrastructure	Premature deterioration of the asset (e.g., service lives that are 10% to 20% shorter than expected, material defects, quality of initial construction)	Improve design and construction practices	Medium	Low
2B	Data Management/ Lack of Data/ Quality of Data	Poor inspection data, improper data stewardship and software limitations	Dedicate full-time inspectors and staff with proper training. Focus more quality assurance and training resources to state-owned system.	Medium	Medium
3B	Funding	Lack of, deferred, or inconsistency of funding (e.g., unexpected budget cuts)	Expand practices to identify more shelf-projects that can be addressed with more funding. Lobby for more funding and better communicate funding needs. Tie expansion projects to maintenance budgets	Medium	Medium
4B	Multimodal Safety	Requests or the ability to widen bridges to accommodate multimodal transportation	If premature replacement due to widening is necessary, communicate loss of service life costs and how it impacts projections	Medium	Medium
5B	Infrastructure Resilience	Unanticipated service interruption due to natural event (e.g., flood, earthquake, adverse weather)	Identify and prioritize bridges in need of debris removal (currently a low priority activity). Use flood vulnerability model output to prioritize areas in need of further checking criticality/loss of structure. Implement Bridge Watch, a GIS-based predictive program for rain events and how they impact existing infrastructure. Bridge Watch sends alerts to maintenance crews to identify bridges that may be impacted.	Medium	Medium

Figure 5-4: Bridge Risks, Ideal Mitigation Strategy and Rating, 1 of 2

RISK CODE	RISK CATEGORY	RISK	IDEAL MITIGATION STRATEGY	CURRENT RISK RATING	POST MITIGATION RISK RATING
6B	Continuity of Operations	Shortage of workforce, lack of qualified replacement candidates (e.g., early retirements and hiring freezes)	Improve recruiting practices, change job requirements for certain positions and improve cross-training	Medium	Medium
7B	Infrastructure Resilience	Unanticipated service interruption due to asset condition	Identify critical elements, increase the inspection/monitoring frequency, including better access for equipment and traffic control	Medium	Medium
8B	Infrastructure Resilience	Unanticipated service interruption due to human-caused events (e.g., crashes, damage from construction activities)	Identify which assets have had repeat hits and are considered high-risk. Install warning systems and cameras at high-risk locations (lower cost option than replacements) OR Meet standards for high-risk locations before planning replacements.	Medium	Medium
9B	Response to Disruptive Transportation Technologies	Autonomous trucking legislation and an increase in truckload capacity may increase the design load for bridges	Understand proposals, identify what challenges they pose and make changes accordingly	Medium	Medium
10B	Competing Stakeholder Expectations	Not meeting federal condition targets	Receive adequate funding to fully implement the current mitigation strategy. Base federal targets on an element-level approach	Low	Very Low
11B	Integration	Inability to manage assets to the lowest life-cycle cost (e.g., preventive activities not performed on a timely basis)	Fully implement using an element-based bridge health-index and preventive maintenance performance measure	Medium	Medium

Figure 5-5: Buildings Risks, Ideal Mitigation Strategy and Rating

RISK CODE	RISK CATEGORY	RISK	IDEAL MITIGATION STRATEGY	CURRENT RISK RATING	POST MITIGATION RISK RATING
1BLDG	Aging Infrastructure	Temporary or permanent building closures	Develop a plan for data collection and maintenance	Medium	Medium
2BLDG	Infrastructure Resilience	Efficient building management	*Rest areas and headquarters:* Include Americans with Disabilities Act assessment information in project selection criteria. *All buildings:* Identify communication gaps and find a way to address them	Medium	Medium
3BLDG	Data Management/ Lack of Data/ Quality of Data	Lack of data on equipment and components	Develop a plan for data collection and maintenance	Low	Low
4BLDG	Funding	Lack of dedicated capital, operations and maintenance funding	Implement the Facilities Asset Management Plan	Medium	Medium
5BLDG	Competing Stakeholder Expectations	Competing stakeholder expectations	Implement the Facilities Asset Management Plan	Medium	Medium
6BLDG	Continuity of Operations	Increasing maintenance equipment and material sizes (e.g., including tow plows, tandems, tanks, brine)	Design based on truck station standards manual	Medium	Medium
7BLDG	Response to Disruptive Transportation Technologies	Unforeseen changes in regulatory requirements, travel demands or technology	Identify communication gaps and address them	Medium	Medium

Figure 5-6: Highway Culverts and Deep Stormwater Tunnels Risks, Ideal Mitigation Strategy and Rating, 1 of 2

RISK CODE	RISK CATEGORY	RISK	IDEAL MITIGATION STRATEGY	CURRENT RISK RATING	POST MITIGATION RISK RATING
1HCDST	Data Management/ Lack of Data/ Quality of Data	Difficulty in getting inspections done by local agencies on shared tunnel system	Inspect tunnels according to inspection schedules (local jurisdictions conduct inspections on tunnels with shared water)	Medium	Mitigate Risk
2HCDST	Aging Infrastructure	Failure/collapse of culvert due to age or lack of maintenance	Rehab culverts before failure occurs and make permanent fixes during future pavement projects	High	High
3HCDST	Aging Infrastructure	Inability to manage culverts to lowest life cycle cost	Better model and research deterioration. Address culvert needs earlier in pavement project scoping - (e.g., during STIP/CHIP development)	Medium	Medium
4HCDST	Aging Infrastructure	Failure/collapse of tunnel due to age or lack of maintenance	Perform regular inspections and invest in recommended repairs (follow ideal LCP strategy)	Low	Mitigate Risk
5HCDST	Data Management/ Lack of Data/ Quality of Data	Lack of statewide location and inspection data for storm drains causes issues with drainage system and affects the roadway	Collect statewide location inventory and inspection data of storm drains	High	Medium
6HCDST	Funding	Availability of funds or inconsistency in culvert investments	Communicate funding needs (e.g., it's more cost-effective to align culvert replacement with pavement projects; emphasize this approach as an optimization strategy)	Medium	Medium
7HCDST	Infrastructure Resilience	Flooding and deterioration due to lack of culvert capacity, resulting in adverse impacts to properties and roadway user safety	Formalize the process of checking hydraulic capacity and the availability of existing culvert storage when deciding whether to line it. Keep track of culverts in areas with flooding problems to determine if they need repair.	Medium	Low

Figure 5-6: Highway Culverts and Deep Stormwater Tunnels Risks, Ideal Mitigation Strategy and Rating, 2 of 2

RISK CODE	RISK CATEGORY	RISK	IDEAL MITIGATION STRATEGY	CURRENT RISK RATING	POST MITIGATION RISK RATING
8HCDST	Infrastructure Resilience	Flooding and deterioration due to a lack of tunnel capacity, resulting in adverse impacts to property and roadway user safety	Add recommended tunnel capacity	Medium	Mitigate Risk
9HCDST	Infrastructure Resilience	Significant damage to culverts through human-caused events	Complete location inventory, continue current inspections and identify damage and repair needs	Medium	Low

Figure 5-7: ITS Risks, Ideal Mitigation Strategy and Rating

RISK CODE	RISK CATEGORY	RISK	IDEAL MITIGATION STRATEGY	CURRENT RISK RATING	POST MITIGATION RISK RATING
1ITS	Funding	Inconsistent operations/ maintenance, funding for staff, equipment and construction	Communicate funding needs. Develop and track performance measures.	High	High
2ITS	Infrastructure Resilience	Standardization in system design, construction issues or system flaws	Update standards in design manual and provide training on standards. Create a construction manual and provide certification training. Create an operations and maintenance manual and provide training.	Medium	Medium
3ITS	Succession Planning	Staff turnover and lack of documentation	Update standards in the design manual and provide training on standards. Create a construction manual and provide certification training. Create an operations and maintenance manual and provide training	High	Medium
4ITS	Integration	Not identifying an appropriate responsible party for maintenance/ operations	Develop workflows	Medium	Low
5ITS	Continuity of Operations	Issues with vendor skills, ability and availability to provide support	Add more details into requests for proposals to ensure support and reliability when selecting potential vendors	Medium	Medium
6ITS	Response to Disruptive Transportation Technologies	Technology shift/ obsolescence	Create plans to address potential obsolescence	Medium	Medium
7ITS	Response to Disruptive Transportation Technologies	Supply availability, equipment shortages and shipping disruptions	Standardize certain materials rather than customizing based on location	Medium	Medium

Figure 5-8: Noise Walls Risks, Ideal Mitigation Strategy and Rating

RISK CODE	RISK CATEGORY	RISK	IDEAL MITIGATION STRATEGY	CURRENT RISK RATING	POST MITIGATION RISK RATING
1NW	Data Management	Not keeping asset inventory and condition data current and consistent in TAMS	Annually collect asset inventory and condition data using LiDAR. Maintain a regular inspection schedule to collect data that LiDAR cannot capture. Inspect noise walls at appropriate frequencies to promptly address fixes.	Medium	Low
2NW	Funding	Noise walls may lack prioritization in funding allocation decisions	Consider noise walls earlier in scoping process to include them in project costs	High	High
3NW	Aging Infrastructure	Not managing noise walls to optimize the life cycle management strategy	Set up work plans for walls based on their age and condition	Medium	Medium
4NW	Integration	Inconsistent application of existing data for capital and preventive maintenance decision making	Set cyclical repair either as part of the inspection process or from TAMS recommendations	Medium	Low
5NW	Competing Stakeholder Expectations	Poor aesthetics of noise are a visual issue for neighbors, whereas structural condition is MnDOT's priority	Fund aesthetics based on performance-based paint specifications (alternatively, MnDOT will prioritize additional funding through other means unless there is dedicated aesthetic funding)	Medium	Medium

Figure 5-9: Overhead Signs Risks, Ideal Mitigation Strategy and Rating

RISK CODE	RISK CATEGORY	RISK	IDEAL MITIGATION STRATEGY	CURRENT RISK RATING	POST MITIGATION RISK RATING
1OS	Aging Infrastructure	Premature deterioration of the asset (e.g., salt corrosion, loose nuts)	Inspect every five years using a standard inspection form to identify overhead signs that may require more frequent inspections. Revise standards (e.g., MnDOT previously used grout but found it led to premature deterioration)	Medium	Medium
2OS	Infrastructure Resilience	Structure design is inadequate for increasing panel sizes	Identify when sign panel sizes are outside of standards. Verify with engineer the use of current design specifications in standard plans.	Low	Low
3OS	Integration or Infrastructure Resilience	Poor construction and/or installation (e.g., post tilt and loose nuts)	Train installers and certify inspectors. Ensure construction inspections are done correctly and any construction flaws are fixed.	High	Medium
4OS	Infrastructure Resilience	Significant damage to asset or structural failure due to human-made or natural events	Develop a new response process and ensure it is understood by all parties. (Continue to focus on response due to an inability to predict these events.)	High	High
5OS	Succession Planning or Continuity of Operations	Shortage of workforce, retirements and documentation	Train and hire staffing concurrently. Foster consistent documentation standards across districts.	Medium	Medium
6OS	Response to Disruptive Transportation Technologies	Unforeseen changes in regulatory requirements, travel demands or technology	Pilot new technology with experimental projects before widespread implementation	Low	Low

Figure 5-10: Pedestrian Infrastructure Risks, Ideal Mitigation Strategy and Rating, 1 of 2

RISK CODE	RISK CATEGORY	RISK	IDEAL MITIGATION STRATEGY	CURRENT RISK RATING	POST MITIGATION RISK RATING
1PED	Data Management/ Lack of Data/ Quality of Data	Current approach to collecting inventory and condition data is labor intensive and the data cycle is 10 years	Collect pedestrian assets using mobile LiDAR	Medium	Low
2PED	Aging Infrastructure	Not meeting federal ADA compliance or its intent	Develop and pilot performance measures for maintaining pedestrian facilities in partnership with local jurisdictions. Identify consistent maintenance approaches to better define responsibilities included in maintenance agreements under cooperative agreements and in master maintenance agreements.	Medium	Medium
3PED	Aging Infrastructure	Difficulty following a life cycle management strategy	Fully integrate assets into TAMS work order process. Develop MnDOT guidance on best practices for maintenance of pedestrian assets	High	High
4PED	Succession Planning	Staff turnover limits the ADA program's ability to address liability, essential services and ADA planning at the district and project level	Increase capacity among existing staff and hire additional staff at the district level	High	Medium
5PED	Infrastructure Resilience	Poor planning, design and/or construction	Continue current control and mitigation strategies. Incorporate 3D modeling to improve planning, design and construction.	Medium	Medium

Figure 5-10: Pedestrian Infrastructure Risks, Ideal Mitigation Strategy and Rating, 2 of 2

RISK CODE	RISK CATEGORY	RISK	IDEAL MITIGATION STRATEGY	CURRENT RISK RATING	POST MITIGATION RISK RATING
6PED	Continuity of Operations	Not receiving local consent/agreement resulting in a lack of operations/maintenance and oversight that leads to premature deterioration	Implement the master maintenance agreements	Medium	Medium
7PED	Competing Stakeholder Expectations	Not meeting the needs of system users	Develop performance measures based on location, type of repair and response timeframe to address complaints. Identify trends to support a more proactive approach.	Medium	Medium

Figure 5-11: Traffic Signal, Lighting and High-Mast Light Towers Risks, Ideal Mitigation Strategy and Rating, 1 of 2

RISK CODE	RISK CATEGORY	RISK	IDEAL MITIGATION STRATEGY	CURRENT RISK RATING	POST MITIGATION RISK RATING
1SLHMT	Aging Infrastructure	Not managing assets appropriately resulting in poor asset condition, which impacts the safety of the traveling public	Ensure adequate staffing for structural inspection throughout asset life cycle. Develop life cycle replacement or preservation program for standalone projects	Medium	Mitigate Risk
2SLHMT	Funding	Lack of consistent dedicated funding/ staffing limits the ability to effectively manage and operate existing assets	Document and communicate needs (e.g., business plans)	High	High
3SLHMT	Infrastructure Resilience	Premature deterioration due to extreme weather or environmental factors	Continue to follow through and fully implement "in-process" mitigation strategies. Have trained inspectors inspect assets during construction.	High	Medium

Figure 5-11: Traffic Signal, Lighting and High-Mast Light Towers Risks, Ideal Mitigation Strategy and Rating, 2 of 2

RISK CODE	RISK CATEGORY	RISK	IDEAL MITIGATION STRATEGY	CURRENT RISK RATING	POST MITIGATION RISK RATING
4SLHMT	Infrastructure Resilience	Damage due to hits by traveling public	Increase resources to respond to incidents more quickly (there are several options for prevention, but none that are based on competing factors)	High	High
5SLHMT	Response to Disruptive Transportation Technologies	Cybersecurity breaches or hardware/software incompatibility and upgrades	Use more secure passwords (Cybersecurity mitigation provided through MNIT). Add locks to cabinets, mostly done through vendors	High	Medium
6SLHMT	Infrastructure Resilience	Poor construction, installation, design specifications or fabrication	Need dedicated statewide construction inspectors trained in signals and lighting (e.g., electrical components)	Medium	Medium
7SLHMT	Continuity of Operations	Power outages result in a non-operational system	Modernize tunnel lighting by providing backup power systems (focus on tunnels due to more critical safety risks). Communicate to the traveling public when systems are out of operation.	High	High
8SLHMT	Multimodal Safety	Signal inoperability results in decreased safety benefits to the traveling public and negative perceptions of how MnDOT manages assets	Continue to upgrade equipment to the central system. Follow life cycle management strategy on all equipment to minimize failures	Medium	Medium
9SLHMT	Multimodal Safety	Lighting inoperability results in decreased safety benefits to the traveling public and negative perceptions of how MnDOT manages assets	Follow life cycle management strategy on all equipment to minimize failures	Medium	Medium
10SLHMT	Response to Disruptive Transportation Technologies	Poor traffic signal timing results in increased user delay and crashes	Implement signal timing performance measure (e.g., retime on-demand as needed)	Medium	Medium

RISK MITIGATION PRIORITIZATION

Figure 5-12: Risk Prioritization Scoring Criteria

Risk Management Priorities	Score
Aging Infrastructure	1
Data Management + Quality	2
Funding	3
Infrastructure Resilience	4
Multimodal Safety	5
Competing Stakeholder Expectations	6
Continuity Of Operations	7
Response to Disruptive Transportation Technologies	8

Risk reduction	Score
Reduction to No Risk	0
High → Medium	1
Medium → Low	2
High → High	3
Medium → Medium	4
Low → Low	5

Cost estimate	Score
No cost	1
$ = Less than $50K	2
$$ = $50K to $250K	3
$$$ = about $500K	4
$$$$ = $1M to $2M	5

The risk assessment process evaluated risks and mitigation strategies and developed a comprehensive prioritization strategy. All asset risk mitigation strategies identified by the workgroups were evaluated based on a relative cost, ability to mitigate the risk and significant risks that agency leadership seeks to address through asset management. The scoring process for risks are documented next.

The risk mitigation strategies are split into three tiers based on the scoring criteria. The tiers are designed to guide workgroups and the agency in action prioritization. Tier one priorities are shown in Figure 5-13. These should be addressed first and are high priority. Tier two priorities are addressed based on available resources. Tier three priorities are tracked but are only addressed after the first two tiers. For a complete breakdown of the components that feed into these tiers see Appendix A.

Figure 5-13: Tier One Risk Mitigation Priorities by Asset Type, 1 of 3

RISK CODE	TIER ONE RISK MITIGATION PRIORITIES	RISK PRIORITY	RISK REDUCTION	COST SCORE	TOTAL SCORE
1P	Pavements: Provide better training for construction inspectors. Change design (or over-design) according to better projections (VMT, HCVMT, ESALs, environmental factors)	1	3	3	7
2P	Pavements: Use various tools to communicate the need/benefit of following the lowest LCP strategy by implementing a regular pavement management schedule	3	3	1	7
3P	Pavements: Identify alternative revenue sources due to reductions from various sources resulting from technological changes. Continue to research how to optimize MnDOT’s dollars	3	3	1	7

Figure 5-13: **Tier One Risk Mitigation Priorities by Asset Type, 2 of 3**

RISK CODE	TIER ONE RISK MITIGATION PRIORITIES	RISK PRIORITY	RISK REDUCTION	COST SCORE	TOTAL SCORE
4P	Pavements: Study cost-benefit of treating ancillary pavements as separate assets independent of mainline using different measures, deterioration modeling, data collection, etc.	2	4	3	9
1B	Bridges: Improve design and construction practices	1	2	1	4
2B	Bridges: Dedicate full-time inspectors and staff with proper training. Focus more quality assurance and training resources to state-owned system	2	4	1	7
3B	Bridges: Expand practices to identify more shelf-projects that can be addressed with more funding. Lobby for more funding and better communicate funding needs. Tie expansion projects to maintenance budgets	3	4	1	8
1BLDG	Buildings: Develop a plan for data collection and maintenance	1	4	1	6
4BLDG	Buildings: for Funding: Implement the Facilities Asset Management Plan	3	4	4	11
1HCDST	Culverts and Deep Stormwater Tunnels: Inspect tunnels according to inspection schedules (local jurisdictions conduct inspections on tunnels with shared water)	2	1	1	4
2HCDST	Culverts and Deep Stormwater Tunnels: Rehab culverts before failure occurs and make permanent fixes during future pavement projects	1	3	1	5
3HCDST	Culverts and Deep Stormwater Tunnels: Better model and research deterioration. Address culvert needs earlier in pavement project scoping-- (e.g., during STIP/ CHIP development)	1	4	1	6
4HCDST	Culverts and Deep Stormwater Tunnels: Perform regular Inspections and invest in recommended repairs (follow ideal LCP strategy)	1	1	5	7
5HCDST	Culverts and Deep Stormwater Tunnels: Collect statewide location inventory and inspection data of storm drains	2	1	5	8
6HCDST	Culverts and Deep Stormwater Tunnels: Communicate funding needs. (e.g., more cost-effective to align culvert replacement with pavement projects; emphasize this approach as an optimization strategy)	3	4	1	8
1ITS	Intelligent Transportation Systems: Communicate funding needs. Develop and track performance measures	3	3	2	8

Figure 5-13: Tier One Risk Mitigation Priorities by Asset Type, 3 of 3

RISK CODE	TIER ONE RISK MITIGATION PRIORITIES	RISK PRIORITY	RISK REDUCTION	COST SCORE	TOTAL SCORE
1NW	Noise Walls: Annually collect asset inventory and condition data using LiDAR. Maintain a regular inspection schedule to collect data that LiDAR cannot capture. Inspect noise walls at appropriate frequencies to promptly address fixes	2	2	3	7
2NW	Noise Walls: Consider noise walls earlier in scoping process to include them in project costs	3	3	1	7
3NW	Noise Walls: Set up work plans for walls based on their age and condition	1	4	3	8
1OS	Overhead Signs: Inspect every five years using a standard inspection form to identify overhead signs that may require more frequent inspections. Revise standards (e.g., MnDOT previously used grout but found it led to premature deterioration)	1	4	1	6
2OS	Overhead Signs: Identify when sign panel sizes are outside of standards. Verify with engineer the use of current design specifications in standard plans	4	2	1	7
3OS	Overhead Signs: Train installers and certify inspectors. Ensure construction inspections are done correctly and any construction flaws are fixed	4	1	2	7
1PED	Pedestrian Infrastructure: Collect pedestrian assets using mobile LiDAR	2	2	3	7
2PED	Pedestrian Infrastructure: Develop and pilot performance measures for maintaining pedestrian facilities in partnership with local jurisdictions. Identify consistent maintenance approaches to better define responsibilities included in maintenance agreements under cooperative agreements and in master maintenance agreements	1	4	3	8
1SLHMT	Traffic Signals, Lighting, and High-Mast Light Towers: Ensure adequate staffing for structural inspection throughout asset life cycle. Develop life cycle replacement or preservation program for standalone projects	1	1	1	3
2SLHMT	Traffic Signals, Lighting, and High-Mast Light Towers: Document and communicate needs (e.g., business plans)	3	3	1	7

RESILIENCE BEYOND THE TAMP

Current planning and future investments at MnDOT are bolstered by a variety of resilience-oriented committees, ongoing studies and existing tools. Some of these activities and resources are listed below.

SUSTAINABLE TRANSPORTATION ADVISORY COUNCIL AND RESILIENCE ADVISORY TEAM

The Sustainable Transportation Advisory Council and the Resilience Advisory Team, a subgroup of the STAC, make recommendations to MnDOT to help the agency reduce carbon pollution from transportation, consistent with the MnDOT statutory goals.

In 2021, the Resilience Advisory Team made several recommendations to improve transportation system resilience in Minnesota. The full MnDOT response to the recommendations can be found on the Sustainable Transportation Advisory Council website. Among those was “Proactive Asset Management.” The guidance suggests that MnDOT strengthen communications and share asset management information across organizations to improve infrastructure sustainability and resiliency. The guidance also supports MnDOT partnering with local departments to implement a robust transportation asset management system that maintains and strengthens the local and state transportation systems. Finally, the agency will offer peer reviews and share information between local, state and national asset managers.

EXTREME FLOOD VULNERABILITY

Climate change has already and will increasingly stress MnDOT’s existing and future assets. Minnesota’s assets are particularly vulnerable to more and heavier rainfalls and high-heat days.

The agency is developing a process to evaluate future flood risk to MnDOT bridges, bridge culverts and pipes. Assessing infrastructure performance with more predicted extreme weather will help MnDOT identify the most at-risk infrastructure. The Extreme Flood Vulnerability Analysis Tool is estimated to be complete in the first half of 2022 and builds off the Flash Flood Vulnerability and Adaption Assessment Pilot Project (2014). The tool gives MnDOT a statewide assessment that identifies overall system needs and guides the deployment of resilience funds. The tool will be used during the development of district resilience plans.

SLOPE VULNERABILITY

MnDOT studies slope vulnerability and risks to the highway system. Rockfalls and landslides can cause significant damage, threaten lives, negatively impact the environment and create lengthy detours.

Recent research has improved MnDOT’s understanding and ability to identify and model vulnerable slopes before slides happen to inform project long-range planning, scoping and public safety. The research used geographic information system and elevation data to highlight at-risk locations along state highways based on features such as slope angle, terrain curvature and lake shoreline proximity.

MEASURING RESILIENCE

MnDOT is developing resilience measures to better understand the effects of climate change on the transportation system and the agency's resilience capacity. The resilience measures will identify high-risk areas, establish a baseline for transportation resilience and use existing measures to gauge the effectiveness of resilience practices in the future. Resilience needs already exceed funding available and these measures will help prioritize strategies, locations and levels of effort to support cost-effective investment decisions.

Below are potential measures of resilience and proxies that MnDOT has identified to measure resilience. This list is dynamic, and measures that ultimately make it onto the list will be based on sound science and engineering principles.

Figure 5-14: Potential Measures of Resilience and Proxies

Note: The cost and effort to track may not exceed the value for some of these measures. An internal review will determine which measures are implemented.

MEASURE OF RESILIENCE OR PROXY	TRACKING STATUS
Significant weather-related damage to infrastructure	Currently tracking
Use of emergency relief funds for repair/rebuild	Currently tracking
Bridge condition rating	Currently tracking
Highway culvert condition rating	Currently tracking
Bridges with scour plan of action	Currently tracking
Pavement condition rating	Existing, not tracked with resilience yet
Pavement performance during extreme heat	Not currently tracked
Bridge overtopping location and frequency	Partially exists but not yet tied to resilience
Wildlife upgraded culverts (aquatic organism passage) where appropriate	Not currently tracked
Slope failure location and frequency	Not currently tracked
Slope vulnerability rating	Existing but not tracked with resilience yet
Minor flood damage (under $5,000) location and frequency	Not currently tracked
Frequency and cost of mobilization and debris removal	Not currently tracked
Weather-related construction delays and damages	Not currently tracked
Resilience upgrades (e.g., slope armoring, raising of roadway)	Not currently tracked
Road closure location and frequency (when weather-related)	Not currently tracked
Installation of green infrastructure (acres, total dollars or projects)	Not currently tracked
Conveyance failures	Not currently tracked
Stormwater facility failures	Not currently tracked
Asset vulnerability to projected precipitation events (under development)	Not currently tracked

EMERGENCY RESPONSE EVENTS

The Federal Highway Administration requires state DOTs to conduct periodic evaluations of facilities that repeatedly need repair and reconstruction due to 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.

Initially, MnDOT did not have a comprehensive spatial database with all the necessary data to conduct this analysis. This requirement resulted in the development of a geodatabase containing a list of projects that have used emergency response funds from 1993 to 2019. The best available data was extracted from Detailed Damage Inspection Reports, the Program and Project Management System, the Fiscal Management Information System and other project description documents or systems. The list of emergency response projects was then mapped using MnDOT's Linear Referencing System in GIS software.

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

The 2022 analysis found a total of 35 locations where there were repeat emergency response events and funds were requested. Figures 5-16 to 5-19 show the location of state highway segments with multiple emergency events since 1993. Sites are in three regions: northwest Minnesota along the Red River, southeast Minnesota along the Mississippi River and south-central along the Minnesota River. MnDOT will continue to monitor vulnerable locations and look for opportunities to make improvements that mitigate the risk of future emergency events.

Figure 5-15: List of Locations with Multiple Emergency Response Events

COUNTY	ROUTE	EVENT YEARS	EVENT TYPE	FHWA PROJECT NUMBERS
Blue Earth	MN-66	1996, 2014	Flooding	MN14221, MN96220
Brown	MN-4	1997, 2014	Flooding	MN14223, MN97250
Carver	MN-101	2010, 2011	Flooding	MN11219, MN10520
Fillmore	MN-43	2007, 2013	Flooding	MN13208, MN13405, MN07508
Fillmore	MN-250	2007, 2013	Flooding	MN13403, MN13206, MN07506
Hennepin/ Scott	US-169	2011, 2014	Bridge Repair	MN14255, MN11221, MN11425
Houston	MN-26	2007, 2013	Flooding	MN13207, MN13404, MN07505
Houston/ Wabasha/ Winona	US-61	2007, 2010, 2012	Flooding	MN12273, MN10308, MN10309, MN10312, MN10503, MN10505, MN10506, MN10507, MN07507
Houston	MN-76	2007, 2013	Flooding	MN13402, MN13205, MN13401, MN13203, MN13204, MN07508
Kittson	MN-175	2006, 2019	Flooding	MN19402, MN06108
Koochiching	MN-11	2002, 2014	Flooding	MN14211, MN02300
Le Sueur	MN-19	2011, 2014	Flooding	MN14239, MN14419, MN14415, MN14226, MN14225, MN11216
Marshall	MN-1	2006, 2009, 2010, 2011	Flooding	MN11413, MN10202, MN10400, MN09422, MN06220
Marshall	MN-220	2002, 2006, 2009, 2010	Flooding	MN10203, MN09422, MN06223, MN02300
Nicollet	US-169	2010, 2011, 2012	Flooding	MN11423, MN10328, MN10526
Norman	MN-9	2006, 2010	Flooding	MN10202, MN10400, MN06106, MN06221
Norman	MN-200	2006, 2010	Flooding	MN10202, MN10400, MN06106, MN06222
Sibley	MN-93	2011, 2014	Flooding	MN14238, MN14215, MN14411, MN11211, MN11215
Wabasha	MN-60	2007, 2010	Flooding	MN10502, MN10321, MN10318, MN10307, MN10504, MN07507
Wabasha	US-63	2007, 2010	Flooding	MN10511, MN10319, MN07516
Wabasha/ Winona	MN-74	2007, 2010	Flooding	MN10509, MN07506
Winona	US-14	2007, 2010	Flooding	MN10507, MN07504
Wilkin	US-75	2006, 2011	Flooding	MN11407, MN06107

Figure 5-16: Emergency Response Roadway Segments 1993-2019 - Northwest Minnesota

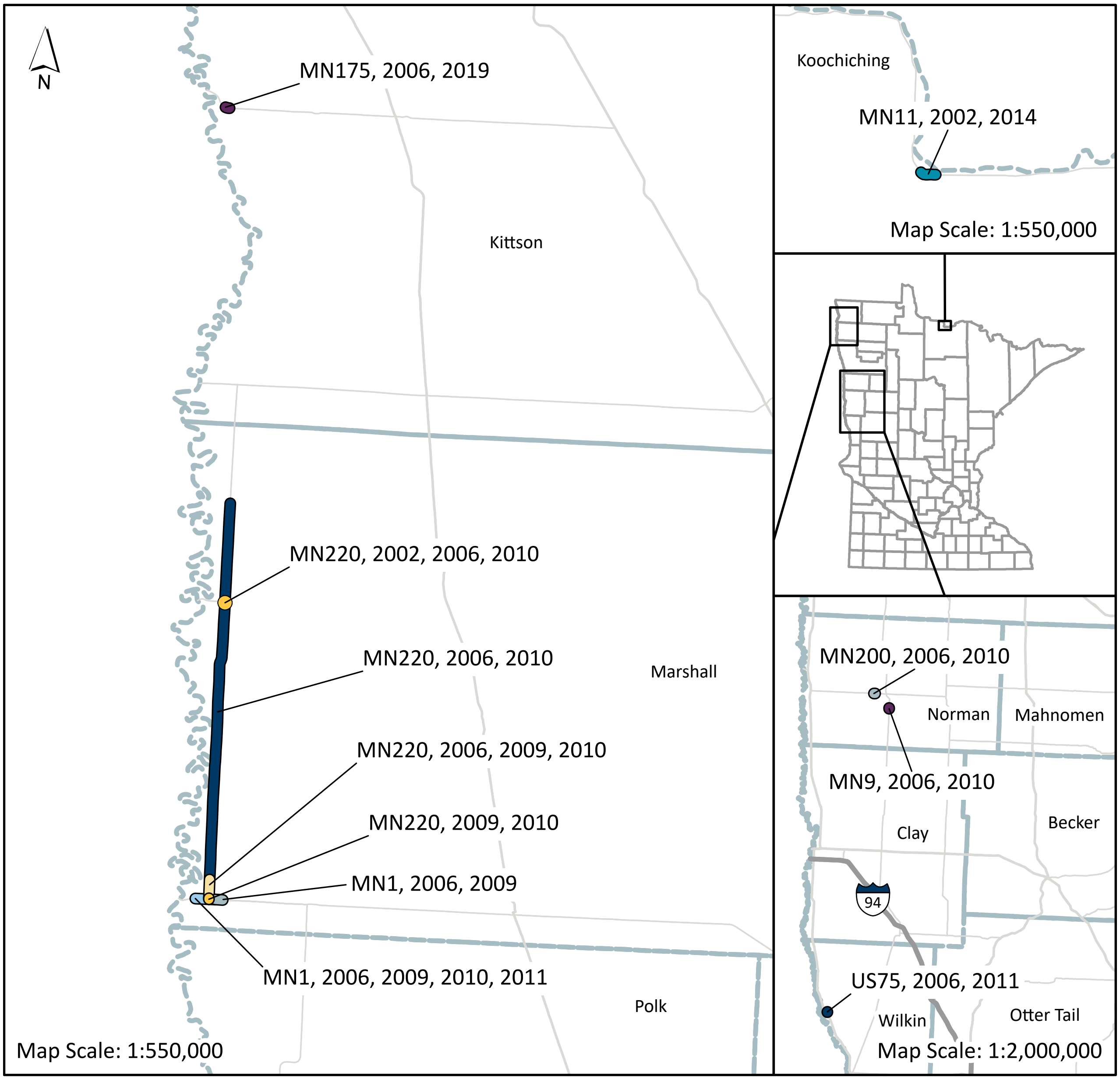


Figure 5-17: Emergency Response Roadway Segments 1993-2019 - Minnesota River

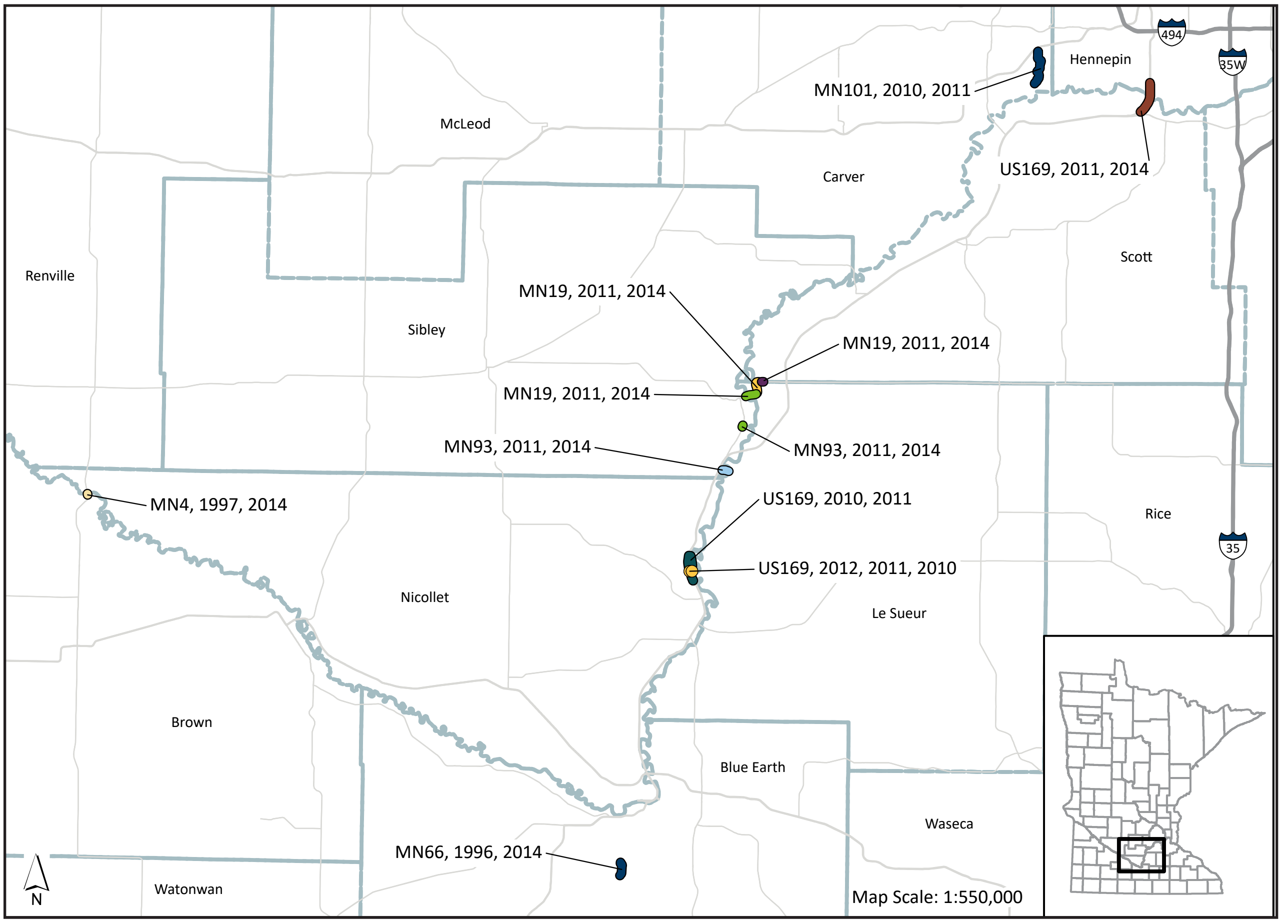


Figure 5-18: Emergency Response Roadway Segments 1993-2019 - Mississippi River

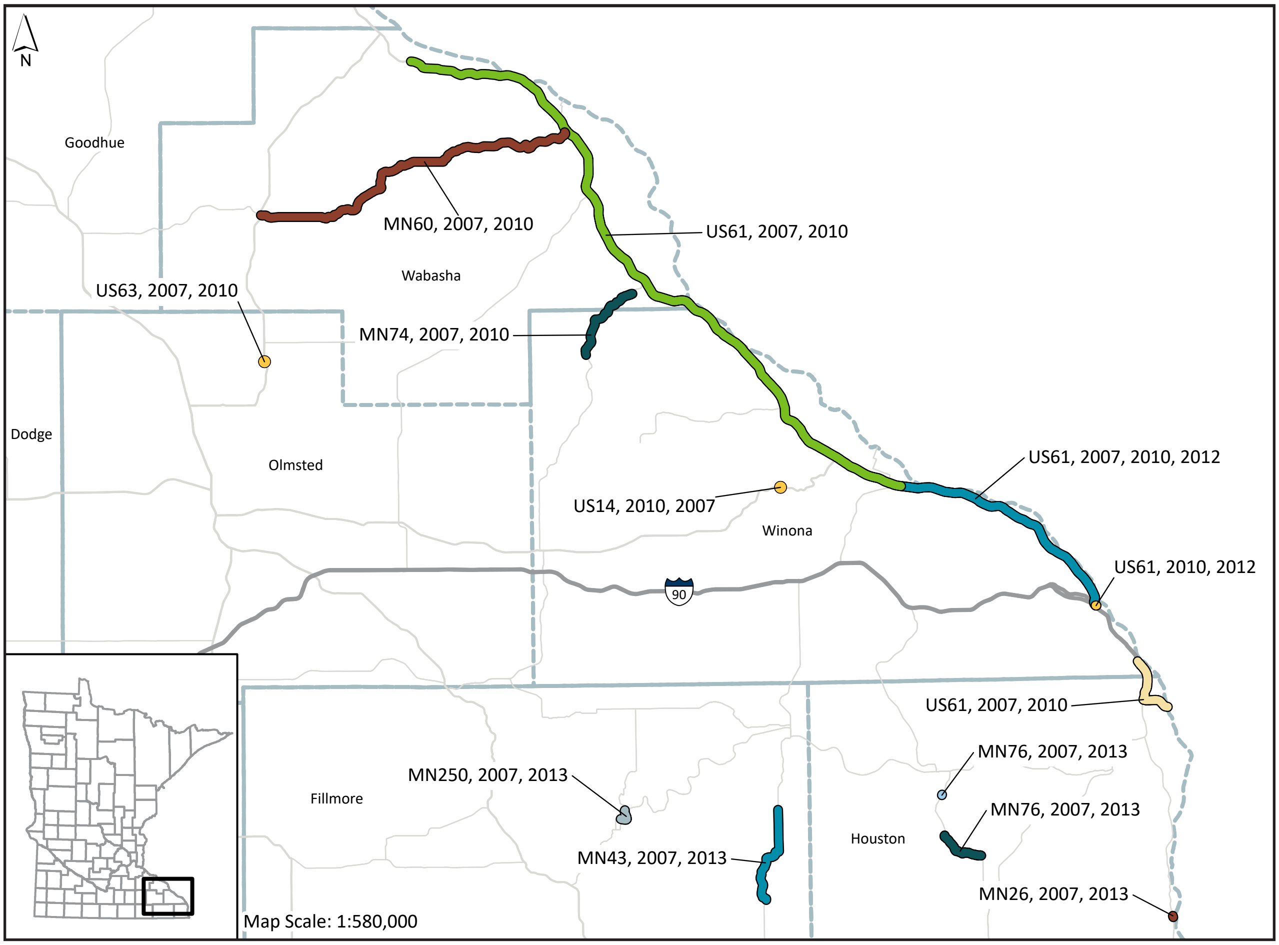
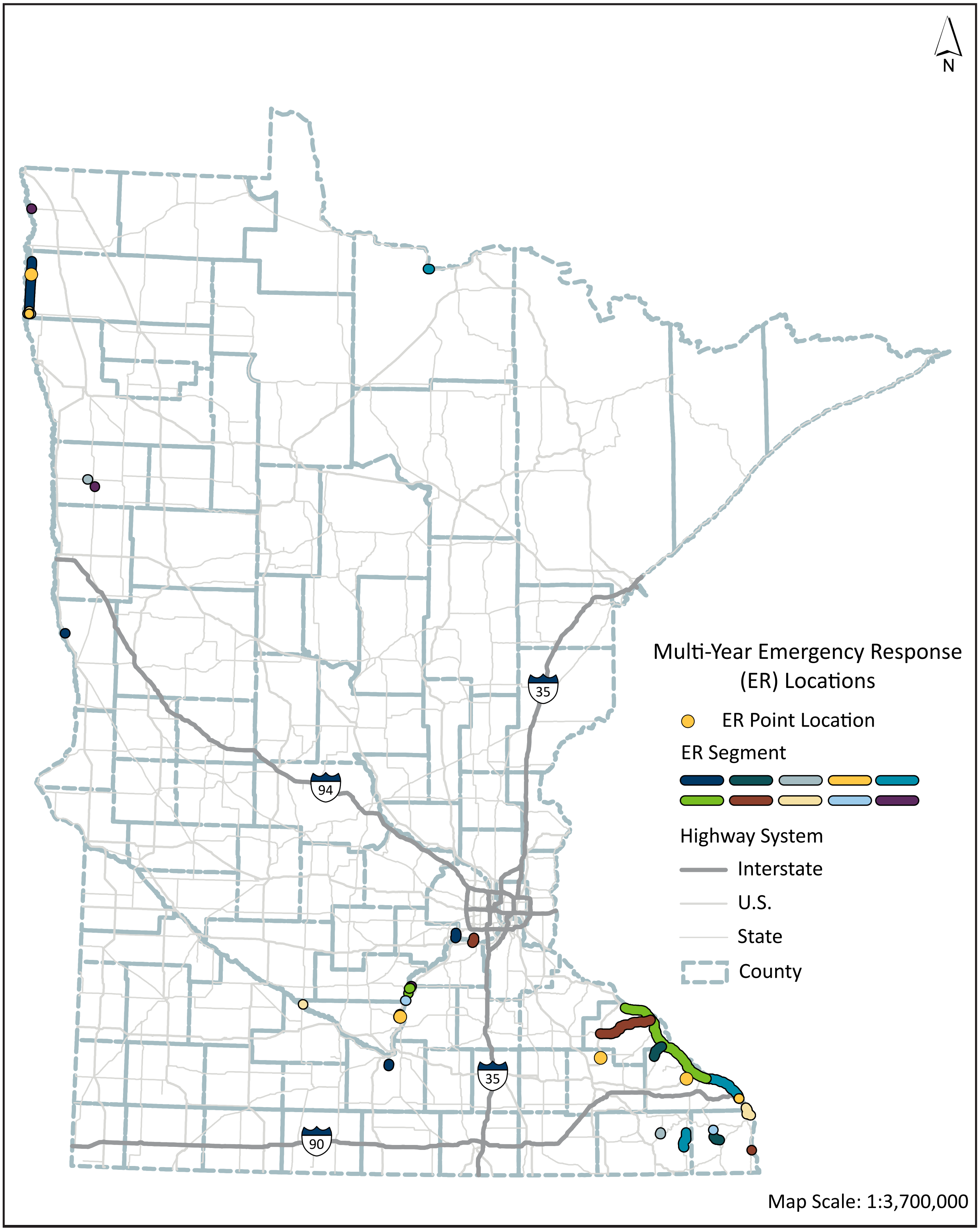


Figure 5-19: Emergency Response Roadway Segments 1993-2019 - Statewide



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LIFE CYCLE PLANNING

Life Cycle Planning, as defined by the Federal Highway Administration, 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.” LCP is used to compare alternate strategies that fulfill the same performance requirements but differ with respect to construction, maintenance and operational costs. These can be compared in terms of the total costs over the entire life cycle of the asset. A question that LCP helps 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?

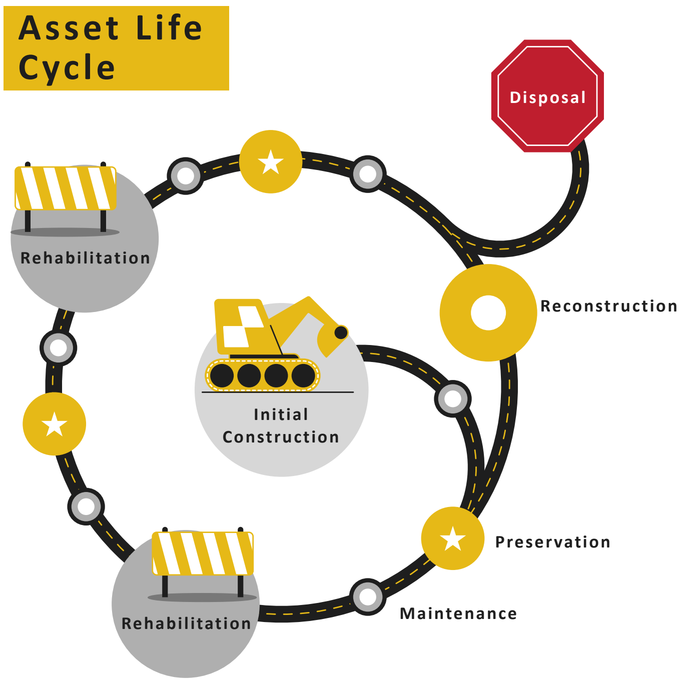
Figure 6-1 illustrates a generic asset life cycle, where different treatments are applied at different times over the life of the asset. Asset management uses asset condition information and analysis techniques to determine the appropriate treatment for each asset and the right time to apply that treatment. A key goal of LCP is to manage assets at the optimal level of preservation where life cycle costs are kept to a minimum.

As part of the TAMP, MnDOT’s LCP objectives are to:

- Establish a long-term focus for improving and preserving the system
- Improve infrastructure asset resilience to climate change and extreme weather events
- 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
- Demonstrate good stewardship to internal and external stakeholders

LIFE CYCLE PLANNING APPROACH

Figure 6-1: Asset Life Cycle Stages



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.

When a new asset is built, the state commits not only to the initial construction costs, but also to the future costs of maintaining and operating that asset. Over a long 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.

Annual operational investments have not been included in the LCP analyses. 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, utility and other indirect costs associated with transportation assets comprise total cost of ownership. For example, MnDOT spends between $80 million and $150 million annually on snow and ice removal on roadways, depending on the severity of the winter. These operational requirements significantly impact the amount of funding available for asset maintenance and rehabilitation activities.

MnDOT minimizes life cycle costs by consistently reviewing asset treatments, adopting new actions suggested by management systems and considering both capital and maintenance costs.

PLANNING FOR RESILIENCE

Climate and extreme weather events pose risks to Minnesota's transportation infrastructure. Unexpected events and long-term changes caused by these risks can have broad social, economic and environmental consequences. MnDOT is committed to providing a resilient transportation system that serves Minnesota as our climate changes. The agency's 20-Year Statewide Multimodal Transportation Plan identified transportation system resilience as a key concept. While it is not realistic to entirely prevent the impacts of climate change, agencies can implement adaptation strategies to cost-effectively minimize risks and help infrastructure become more resilient.

The first steps towards building a more resilient transportation infrastructure system are to identify the most significant risks and assess system vulnerability to these risks. The risks related to resilience are discussed in **Chapter 5: Risk Management**.

MnDOT is exploring a range of strategies to implement at various asset life cycle stages to increase the resilience of assets to environmental risks. These strategies include:

Material selection. Use of pavement materials that are less susceptible to extreme temperature and moisture variations.

Design approaches. Use design standards to improve structural support and drainage e.g., armoring slopes along roads to mitigate roadway overtopping and reduce impacts of flooding. Guidance for these approaches include the 2014 Flood Mitigation Program, the Aquatic Organism Passage Guide, and consideration of geomorphic design in floodplain culverts.

Construction procedures. Adjust construction timing to reduce construction during hotter months, add flexibility in construction schedule to accommodate heavy precipitation events that could impact project schedule, and improve finishing and curing practices.

Maintenance and operation activities. Increased efforts to seal cracks and joints in existing pavements, adjustment of spring thaw load restrictions, use of asphalt pavement preservation techniques that reduce surface course binder aging (e.g., chip seals, fog seals, microsurfacing), maintenance of high friction pavement surfaces, employment of nondestructive methods to determine pavement structural adequacy in inundated/flood condition to determine structural loading restrictions after inundation events, and increase debris removal and inspection around bridges. Examples of this include the salt management program and native and resilient plantings.

Extreme weather can influence asset management strategies over the long term, and MnDOT considers these risks and adaption approaches while developing the LCP strategies. MnDOT considers a balance between preservation and major rehabilitation/reconstruction to ensure pavements continue to provide a good level of service for the road users. MnDOT also is working to identify pavement sections that are more vulnerable to extreme weather to determine if/how funding can be allocated to address climate risks. If a certain portion of MnDOT's pavement network is more vulnerable to extreme weather events, the pavement deterioration models and treatment strategies will be recalibrated to help improve the overall resiliency of the pavement network.

LIFE CYCLE PLANNING IMPROVEMENTS

In the previous TAMP, MnDOT approached LCP from a project-level perspective. For each asset class, MnDOT evaluated the total cost of maintaining a typical asset over its whole life based on the treatment strategy used (such as minimum maintenance or preservation-based approach). The exceptions were bridge and highway culverts that used the Markov approach. The project-level analysis did not consider the condition distribution of assets in the network to establish cost and performance outcomes of managing each asset network over the analysis period.

Since the development of the previous TAMP, MnDOT has significantly improved its ability to model treatment costs as they relate to asset condition. This improvement has helped MnDOT shift to a network-level analysis of system performance that not only considers current and predicted condition distribution of assets over the long term, but also includes an evaluation of the level of performance expected to be achieved based on several life cycle treatment approaches (e.g., worst-first strategy, MnDOT's current treatment strategy, and MnDOT's desired treatment strategy). The treatment strategies evaluated vary based on the asset type and more details are provided in the following sections.

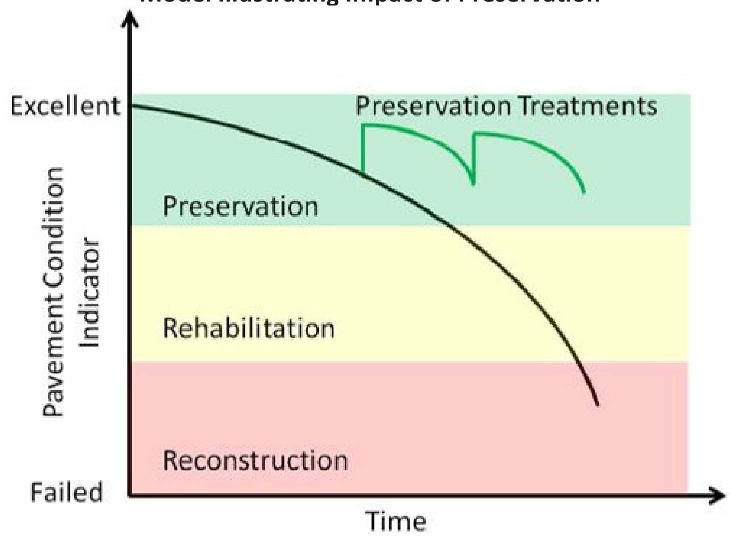
PAVEMENT LIFE CYCLE PLANNING

The current asset value of the National Highway System, other NHS and non-NHS pavements is $22.5 billion. These high values demonstrate the need for a sound framework and methodology to manage these assets effectively over their life cycle.

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. A typical pavement deterioration model demonstrating the impact of preservation is illustrated in Figure 6-2.

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

Figure 6-2: Pavement Condition Deterioration Model Illustrating Impact of Preservation



- Creating the [MnDOT Pavement Preservation Manual.]
- Staffing a liaison position for the Office of Materials and Road Research and districts. The role primarily focuses on getting the right technology and information to the district offices.
- Building preventive maintenance treatments into its Pavement Management System decision trees.
- Developing a Pavement Investment Guide, and modifying pavement management software to allow districts to analyze investment scenarios unique to their local areas.
- Assigning the Asset Management Program Office responsibility to work between the Materials Office and district maintenance and materials staff to improve the systematic planning of pavement maintenance activities.
- Developing communication materials that convey the benefits of the work MnDOT employees can perform cost effectively to encourage pride in performing this sort of work.
- Creating and testing performance measures and targets to ensure preventive maintenance treatments are included in district work plans.
- Beginning to incorporate calculated internal maintenance and capital cost implications related to MnSHIP performance scenarios as part of the capital programming process.

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. Commonly used treatments on concrete-surfaced pavements include joint resealing, partial depth repairs, and minor/major concrete pavement restoration activities (e.g., dowel bar retrofit, diamond grinding, full-depth repairs). A listing of the typical pavement treatments and the associated costs is presented in Figure 6-3.

While some of the treatments shown in Figure 6-3 (e.g., chip seals, thin overlays, medium mill and overlay) are applied primarily to extend the service life of the pavement and delay the need for major rehabilitation/ reconstruction activities, certain treatments (e.g., micro-mill and UTBWC, white topping, Minor CPR and grinding) are applied primarily to address safety issues (such as friction loss or hydroplaning due to rutting in the wheel paths). The overall objective is to slow down the rate of deterioration and provide a smooth, durable and safe roadway for the users at the lowest practical life cycle cost.

TOOLS

MnDOT uses a pavement management system that meets the minimum requirements established in 23 CFR 515.17. MnDOT uses treatment decision trees for asphalt and concrete pavements that have been programmed into the PMS. Treatments are triggered based on several factors such as pavement age, type of last treatment action, distress severity and extent and traffic. MnDOT can forecast the deterioration of Interstate, Non-Interstate NHS and Non-NHS pavements using the performance models that have been integrated into the PMS. Treatment costs used in the PMS analysis are routinely reviewed and updated based on actual project costs. The PMS analysis generates treatment recommendations based on the budget level provided using a benefit-cost optimization routine that maximizes the benefit-to-cost ratio.

Figure 6-3: Typical Treatments and Associated Costs for Asphalt-Surfaced Pavements

TREATMENTS	FHWA TREATMENT CATEGORY	COST PER LANE-MILE
Reclaim and Overlay, Urban Regrade, Rural Regrade, Concrete Replacement, Unbonded Concrete Overlay	Reconstruction	$268,000 - $2,615,000
Medium Mill and Overlay, Major Concrete Pavement Restoration and Grinding, Cold In-Place Recycling, Thin Mill and Overlay, Crack/Seal and Thick Overlay, Major Concrete Pavement Restoration, Medium Overlay, Micro-mill and Ultra Thin Bituminous Wearing Course, Minor Concrete Pavement Restoration and Grinding, Reclaim and Whitetopping, Thick Mill and Overlay, Thin Overlay, Ultra Thin Bituminous Wearing Course, Whitetopping, Hot In-Place Recycling	Rehabilitation	$101,000 - $640,000
Chip Seal, Crack Seal, Crack Fill, Joint Seal	Preservation	$3,000 - $31,000

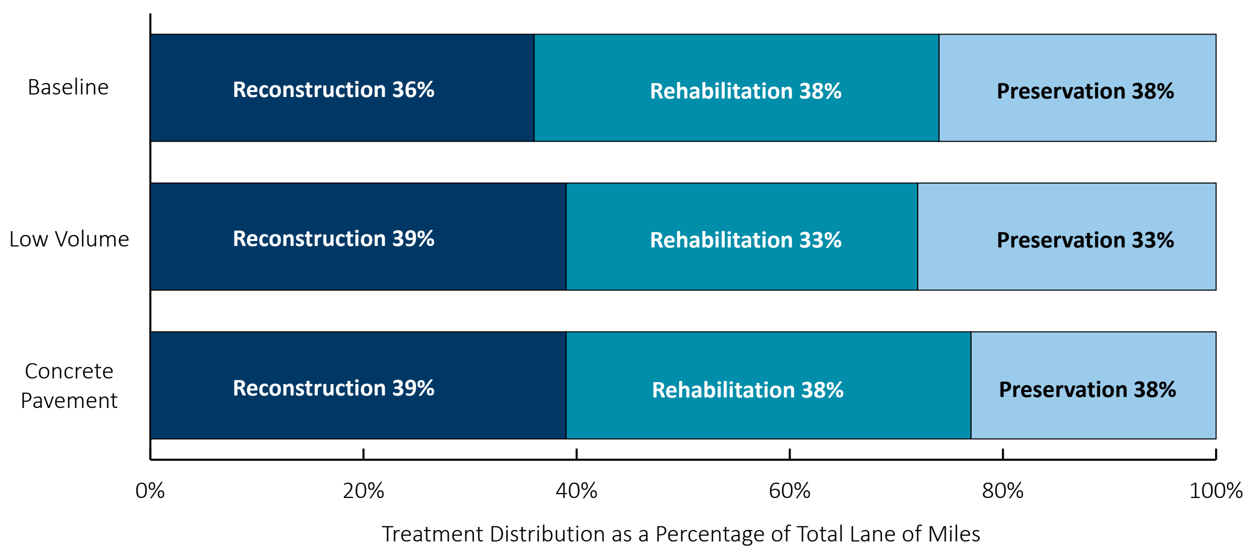
PAVEMENT STRATEGIES

MnDOT evaluated the impact of four LCP strategies on pavement conditions using a 30-year analysis period. A brief description of each strategy is provided below:

- **Strategy #1: Baseline.** This strategy represents MnDOT's current approach of managing its pavement network using a mix of treatments as determined using MnDOT's existing treatment decision trees programmed in the PMS.
- **Strategy #2: Low-Volume Road.** Under this approach, the PMS decision trees were modified to only trigger thin overlay and reclaim and overlay treatments on low-volume roads (with AADT less than 5,000). By limiting the types of treatments on the low-volume roads, this strategy provides more of the available funding to be spent on the higher-volume roads.
- **Strategy #3: Concrete Pavement.** The impact of increasing investments in concrete pavement treatments was investigated under this strategy. A minimum of 100 lane-miles of concrete pavement treatments were triggered over each year of the analysis period. This strategy was suggested because the cost of repairing deteriorated concrete roads is so high that the benefit/cost ratio for these treatments is typically not high enough to be recommended in the PMS.
- **Strategy #4: No Preservation.** Under this strategy, all the available funding is allocated to rehabilitation and reconstruction treatments. This strategy is included to contrast the results with MnDOT's preservation strategy. To conduct this analysis the part of the PMS decision tree that is used to trigger preservation treatments was deactivated. This strategy was eventually dropped from the analysis as the workgroup felt the results didn't accurately reflect the impacts of removing preservation investments. More discussion on this approach is in the Takeaways section.

Figure 6-4 illustrates the distribution of preservation, rehabilitation and reconstruction actions (based on lane-miles) for each LCP strategy evaluated.

Figure 6-4: Treatment Distribution Based on Lane-Miles for Pavement Strategies



ANALYSIS RESULTS

The main LCP inputs are summarized below:

- Analysis period: 30 years (2020 through 2049)
- Base year (2020) budget level: $600 million
- Average annual budget increase: approximately 3% (to account for expected revenue increase)
- Inflation rate: 5% (to account for increase in treatment costs over time)

The analysis includes projects that have already been programmed or implemented as a part of the STIP and CHIP programs from 2020 through 2026. Due to the uncertainty associated with the accuracy of the performance models for long-term projections, the LCP analysis results are presented only through 2032, which covers the 10-year period (2023 to 2032) addressed in this TAMP.

Figures 6-5 through 6-7 present the pavement condition trends from 2020 through 2032 for each pavement network and LCP strategy evaluated.

Figure 6-5: Interstate Pavement Condition Outcomes of LCP Strategies

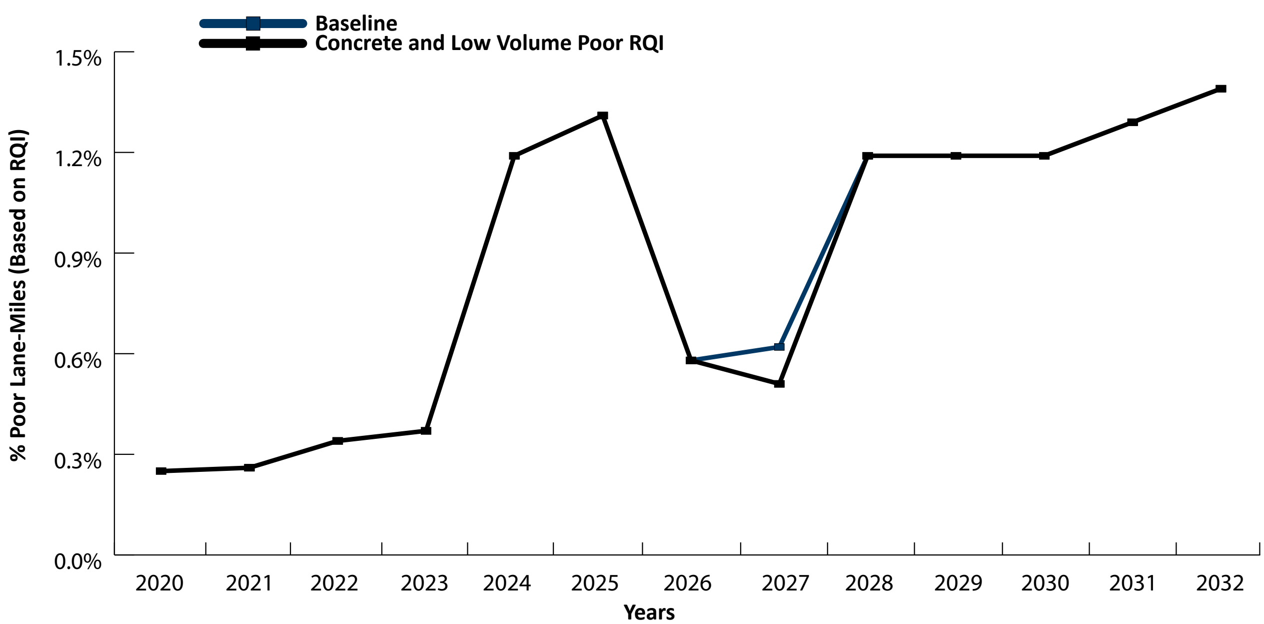


Figure 6-6: Non-Interstate Pavement Condition Outcomes of LCP Strategies

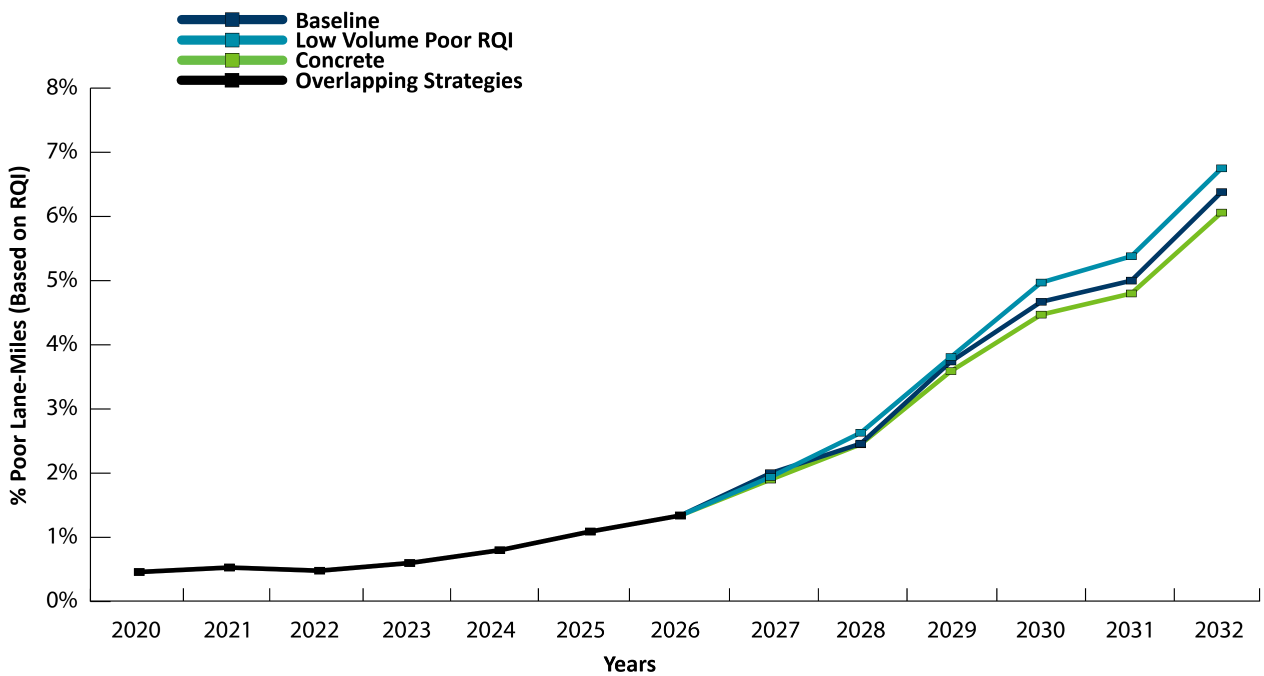
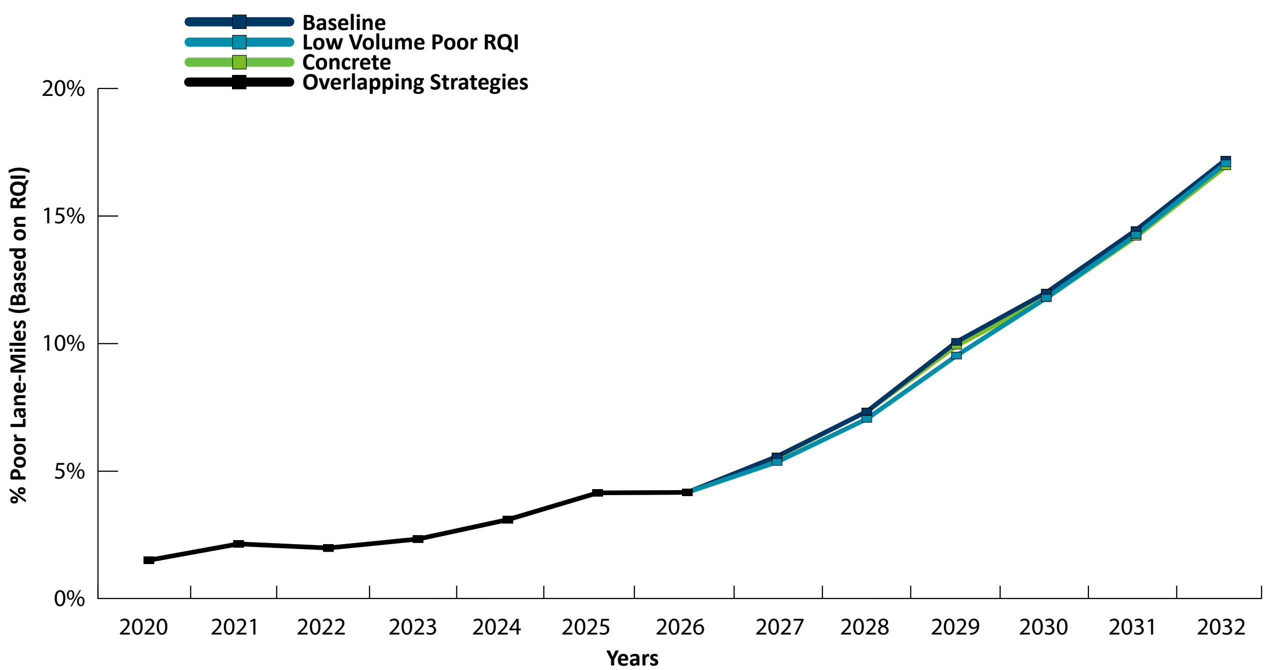


Figure 6-7: Non-NHS Pavement Condition Outcomes of LCP Strategies



TAKEAWAYS

The key takeaways from Figures 6-5 to 6-7 are summarized below:

- In general, all three strategies evaluated result in very similar condition trends through 2032.
- The current level of funding results in declining conditions due to increasing treatment costs, which are not expected to be offset by additional revenues in the future.

The similarity in the analysis results was counter-intuitive so the LCP Work Group investigated possible causes. The overall levels of deterioration shown in the 30-year analyses also raised questions since MnDOT's preservation efforts in recent years have resulted in improved system conditions. The following were found to be contributing factors to the analysis results:

- In 2014, 4.3% of the statewide pavement network was in poor condition and, based on 2020 conditions, only 0.9% of the pavement network is in poor condition. This suggests that the investments that MnDOT has been making in pavement preservation activities have resulted in a significant improvement in performance. However, these improvements do not seem to be reflected in the performance predictions from the PMS. This indicates that the PMS performance models and/or treatment impacts (benefits and condition resets) may need to be recalibrated to result in realistic projections that are more consistent with ground truth.
- Inflation costs in the PMS are greater than the rate at which revenue is increasing.

As a result of these findings, MnDOT is actively working on the following activities:

- Evaluating necessary adjustments to RQI and pavement distress projection models.
- Refining decision tree logic so PMS treatment recommendations better match actual projects being implemented.
- Exploring ways to better capture the impact of pavement preservation activities on performance.

MnDOT is also in the process of implementing a new PMS software and this effort is expected to be completed by early 2023. Additional information on other planned enhancements is documented in **Chapter 8: Implementation and Future Developments**.

USER COST FOR PAVEMENT LIFE CYCLE PLANNING

Although not a direct cost to agency budgets, MnDOT has been encouraged to consider costs to users resulting from its decisions. While all asset management activities impact system users to some degree, pavement maintenance and construction activities are the dominant source of user costs, which can be meaningfully represented by user delay.

In the previous TAMP, MnDOT prepared illustrative life cycle cost analyses' using a "deterministic" modeling approach applied to a hypothetical bituminous pavement section. This allowed readers to visualize the cost effectiveness of various strategies which contained numerous treatment applications over a typical pavement lifecycle.

To estimate user costs, each treatment was assigned a traffic control strategy and attendant user cost based on numerous underlying assumptions, and resulting user costs were compared for the hypothetical pavement section.

In this TAMP, MnDOT has moved to a network level life cycle planning approach using its PMS. As part of the output, discrete projects have been proposed for each year of the analysis. This provided an opportunity to perform a more representative estimate of user costs and as such, MnDOT commissioned a study to more thoroughly assess and model traffic impacts due to pavement work. The following variables are now able to be discretely considered:

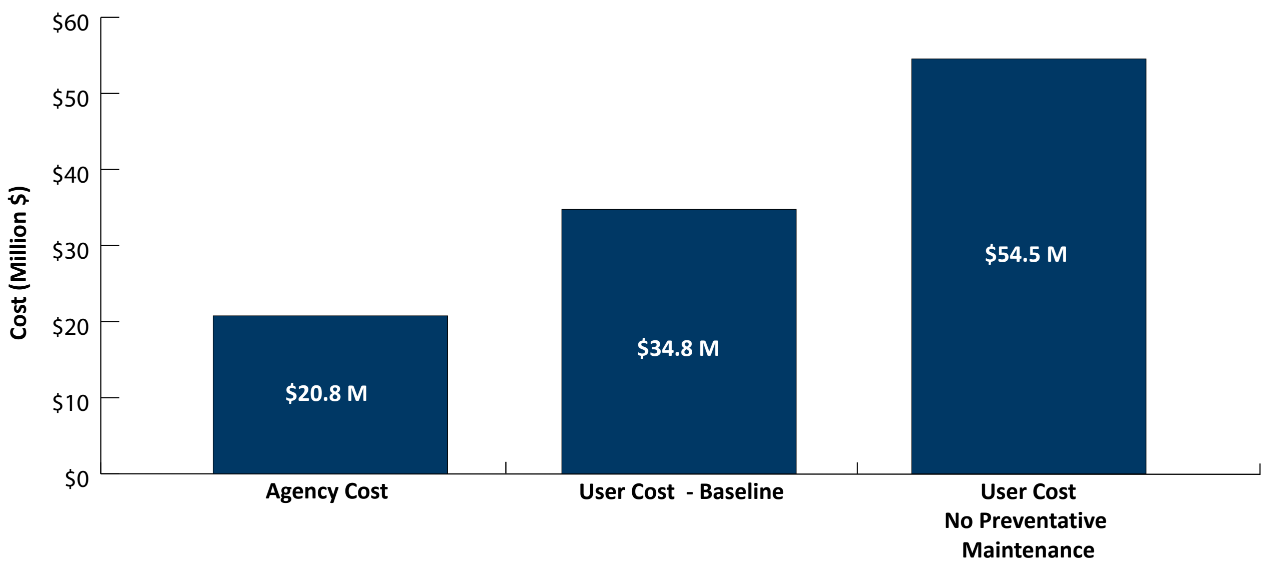
- Pavement management work type
- Length of project
- Traffic volume, including auto and heavy commercial makeup
- Traffic control strategies specific to work types, including work zone length and hours of operation
- Hourly traffic distribution for control strategy
- Traffic queuing characteristics
- Work type "production" rates
- Project duration

This modeling approach was applied to the "Baseline" and "No Preservation" strategy outputs (approximately 6,000 and 4,000 projects respectively) and total user costs were computed.

The results show that:

- Costs to users are substantially higher than agency financial costs for either scenario.
- The user costs for the no PM strategy are 57% higher in comparison to the Baseline strategy ($54.5 billion versus $34.7 billion).
- The Baseline scenario addresses 42% more lane miles over the analysis period than the no PM strategy (39,357 lane miles versus 27,771 lane miles) at significantly lower user cost.

Figure 6-8: Agency Cost versus User Cost for Traffic Delay Due to Construction



BRIDGE LIFE CYCLE PLANNING

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) have a replacement value of approximately $14.6 billion. The service life of most bridges is beyond 50 years and MnDOT works aggressively to extend bridge life by performing preventive maintenance on a routine basis.

Consistent with federal requirements, MnDOT regularly performs a detailed inspection on each of its bridges (usually at two-year intervals, some more or less frequently based on inspection results, as outlined in the MnDOT Bridge and Structure Inspection Program Manual). MnDOT's Bridge Office is required to keep inventory, inspection and condition data on all bridges in the state regardless of ownership. MnDOT performs regular communication and audit of statewide inspection data.

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

Preventive maintenance activities – flushing, crack sealing, joint maintenance, spot painting, and other minor repairs – are typically performed by MnDOT staff, either following a recommended frequency or as needed, based on the element condition documented within SIMS. 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). MnDOT does not always meet bridge preventive maintenance cycles or needs due to staffing, funding constraints, work zone traffic control limitations and competing system priorities. Crack sealing on bridge decks and barrier and poured joint sealing are typically performed on a five-year frequency. Other preventive maintenance activities, such as expansion joint maintenance, as well as reactive maintenance activities, such as patching, are performed in response to conditions noted in the inspection reports and tracked in SIMS.

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

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

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

A listing of typical bridge treatments along with their average unit costs is summarized in Figure 6-9.

Figure 6-9: Cost of Bridge Treatments and Actions

TREATMENTS AND ACTIONS	FHWA TREATMENT CATEGORY	COST
Culvert	Reconstruction	$144 Sq. Ft.
Early Materials	Reconstruction	N/A
New Bridge	Reconstruction	$174 – $302 Sq. Ft.
Pedestrian Bridge	Reconstruction	$1M - $4M per bridge
Temporary Bridge	Reconstruction	N/A
Deck Replacement	Rehabiliation	$74.40 Sq. Ft.
Major Widening	Rehabiliation	$229 Sq. Ft.
Superstructure Replacement	Rehabiliation	$131.60 Sq. Ft.
Bridge Painting	Preservation	$18.60 - $21.70 Sq. Ft.
Deck Overlay	Preservation	$9.70 Sq. Ft.
End Posts	Preservation	$9000 Corner of Bridge
Joint Replacements	Preservation	$1144 - $3432 Linear Foot
Railing or Median Barrier Replacement	Preservation	$225 - $350 Linear Foot
Substructure Repairs or Pier Struts	Preservation	$160 - $200 Linear Foot Substructure. Pier Struts $1100 Linear Foot
Preventive Maintenance (Set aside in STIP and CHIP)	Maintenance	$5.70 - $13.70 Sq Ft
Bridge Portion of BARC (Set aside in STIP and CHIP)	Maintenance	N/A
Crack Sealing	Maintenance	$3.00 Linear Foot

TOOLS

As discussed in **Chapter 2: Asset Management Planning and Programming Framework**, MnDOT uses the Bridge Replacement and Improvement Management tool to conduct a risk-based analysis to establish treatment priorities. The risk level for service interruption (i.e., the bridge is no longer performing as intended) is determined as the product of the likelihood and consequence of failure. A Bridge Planning Index is then calculated on a 1 to 100 scale that incorporates the probability and consequence of service interruption. A BPI of 100 indicates the lowest priority and a BPI of 1 indicates the highest priority.

The probability of a service interruption is based on several factors such as:

- Bridge condition
- Vertical clearance
- Scour
- Load rating
- Fatigue
- Fracture critical members

The consequence of service interruption is determined based on the following parameters:

- Traffic volume
- Detour length
- Bridge length
- Local considerations (industry, trade, agriculture etc.)

BRIDGE STRATEGIES

MnDOT performed a network-level LCP analysis to determine the impact of two LCP strategies on resulting performance outcomes. The analysis used historical condition data to project future deterioration and then schedule work for bridges based on the BRIM decision tree logic. Projects were constrained by available funding and prioritized by risk score BPI. Maintenance costs were then applied to the network, generally bridges in worse condition are more expensive to maintain as they see greater needs for reactive maintenance (but less needs for preventive maintenance).

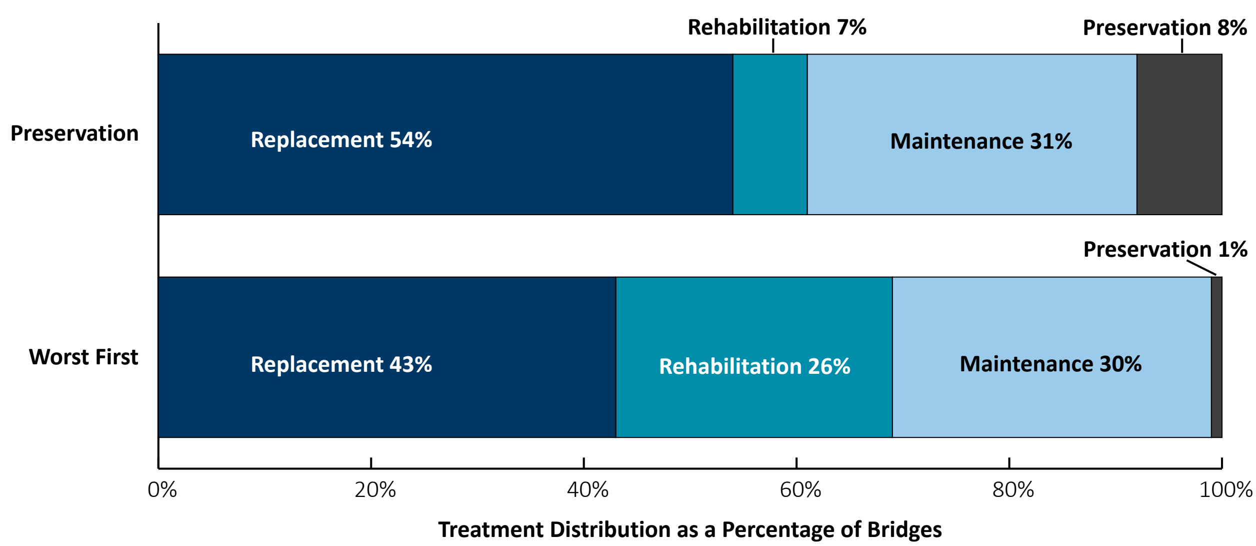
The following LCP strategies were evaluated for bridges:

- **Strategy #1: Preservation.** This strategy balances investments across the different treatment categories (maintenance, preservation, rehabilitation and replacement).
- **Strategy #2: Worst-First.** Under this strategy, all available budget was reserved for funding projects on bridges in poor condition.

For each LCP strategy investigated, the impact of two funding scenarios were evaluated––current funding and unlimited funding (no financial constraints imposed on BRIM analysis).

Figure 6-10 illustrates the distribution of maintenance, preservation, rehabilitation and replacement actions for under the current funding scenario.

Figure 6-10: Treatment Distribution for Bridge Strategies



ANALYSIS RESULTS

The analysis includes projects that have already been programmed or implemented as a part of the STIP and CHIP from 2020 through 2026. The key differences in the funding allocation between the two LCP strategies are:

- The average funding allocated by the preservation strategy between 2021 and 2026 is approximately 65% higher in comparison to the worst-first strategy. This is because the worst-first strategy is backloaded whereas the preservation strategy maintains a consistent funding amount throughout the 10-year period. Between 2027 and 2032, the funding allocation under the worst-first strategy is almost 40% higher due to backloading.
- Between 2021 and 2026, the preservation strategy focuses the investments on NHS bridges whereas the worst-first strategy allocates almost equal priority to both NHS and non-NHS bridges. Between 2027 and 2032, both the preservation and worst-first strategies prioritize investments on NHS bridges.

Figures 6-11 and 6-12 illustrate bridge performance trends from 2022 through 2042 for each bridge network and LCP strategy evaluated.

Figure 6-11: NHS Bridges Condition Outcomes of LCP Strategies

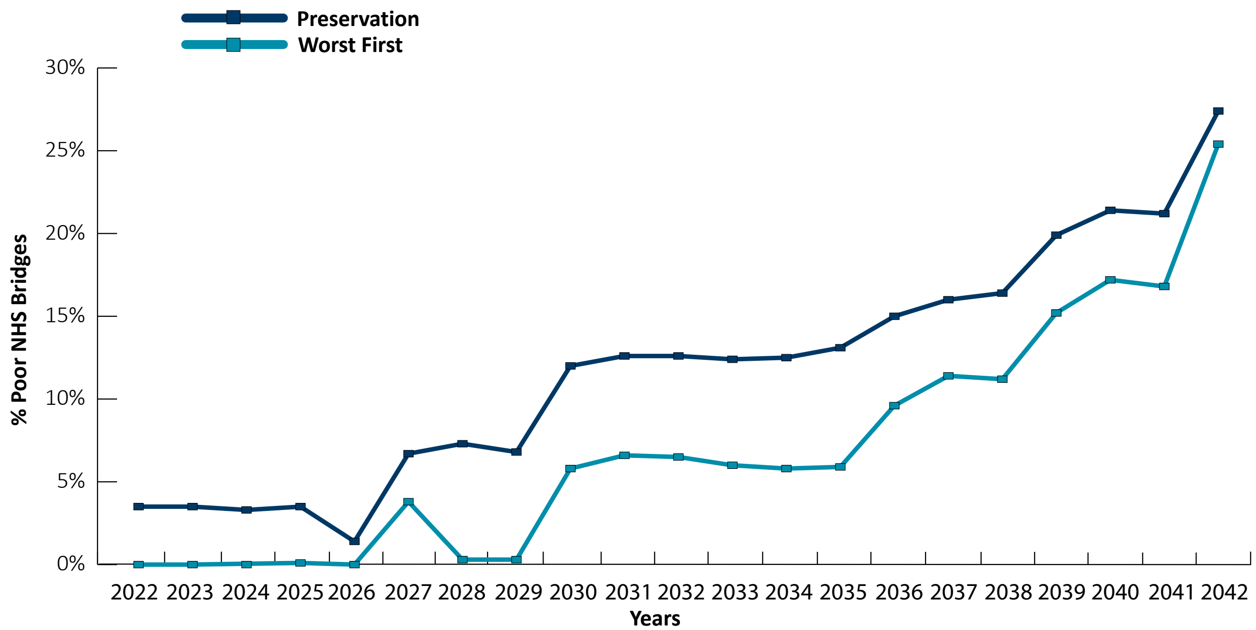
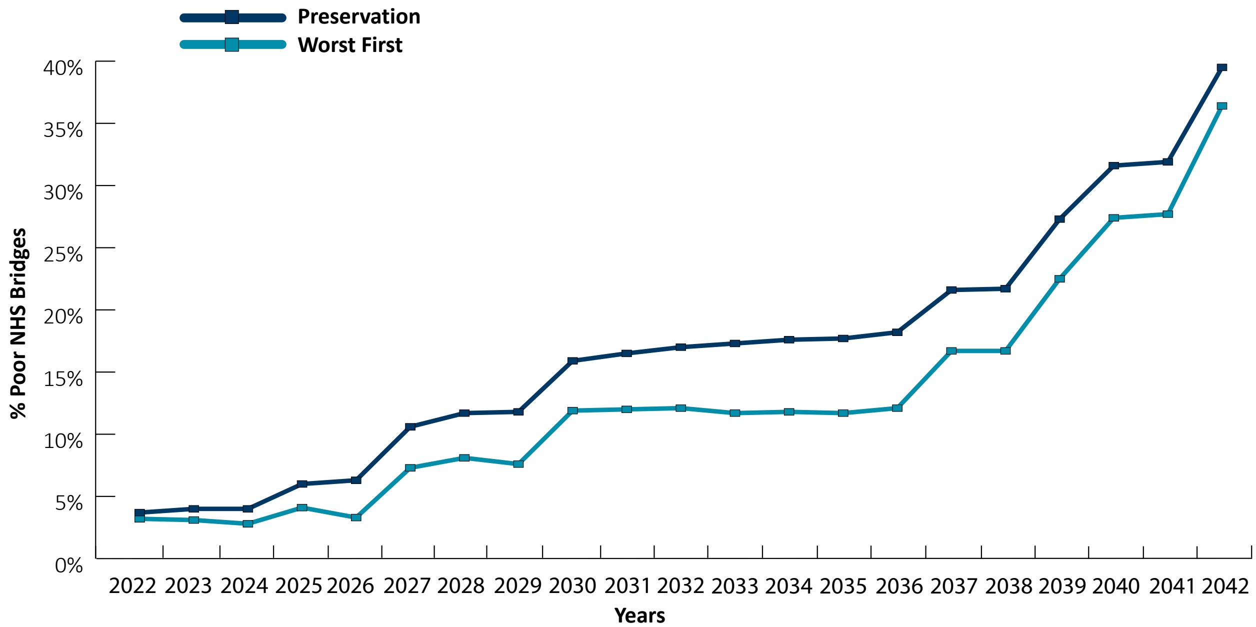


Figure 6-12: Non-NHS Bridges Condition Outcomes of LCP Strategies



TAKEAWAYS

The key takeaways from Figures 6-11 and 6-12 are summarized below:

- The worst-first approach results in better condition outcomes compared to the preservation approach for this fiscally constrained analysis. This is primarily due to prioritizing bridges with poor condition, and shifting them to good, while ignoring bridges that could be maintained in fair. While this may appear attractive in the short term, the long-term effects of managing the program in this manner will be unsustainable as the cost associated with fixing poor bridges is substantially higher than preservation fixes.
- A large percentage of bridges are expected to fall into poor condition by 2032. To meet the established performance targets under the current funding scenario, it is anticipated that most of the work types will have to be replacement and rehabilitation projects even with a preservation-focused program.

MnDOT also evaluated the long-term impacts of the preservation and worst-first strategies under an unconstrained scenario (unlimited budget) and the result are presented in Figures 6-13 and 6-14.

When funding constraints are not imposed on the analysis, it is evident from Figures 6-13 and 6-14 that the preservation strategy results in better performance outcomes over the long term. It improves the fraction of bridges in good condition and reduces the number of bridges in poor condition. The analysis also shows that additional funding or changes to performance targets will need to be made to allow a shift toward a preservation-centric program.

Figure 6-13: Projected 2042 Bridge Conditions––Preservation Strategy (Unconstrained Budget)

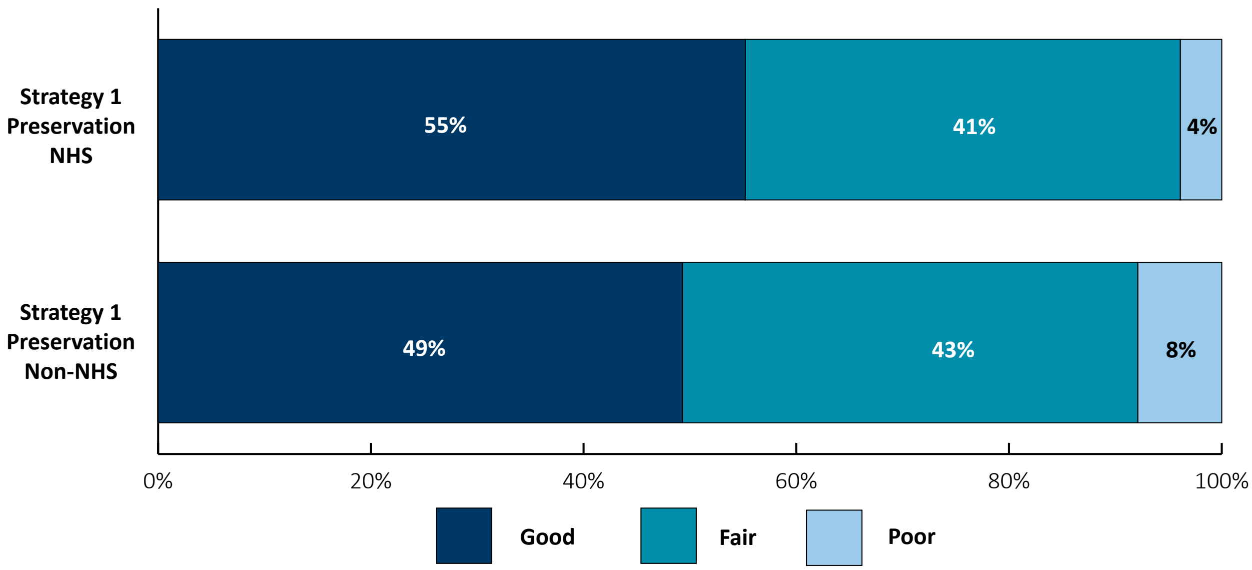
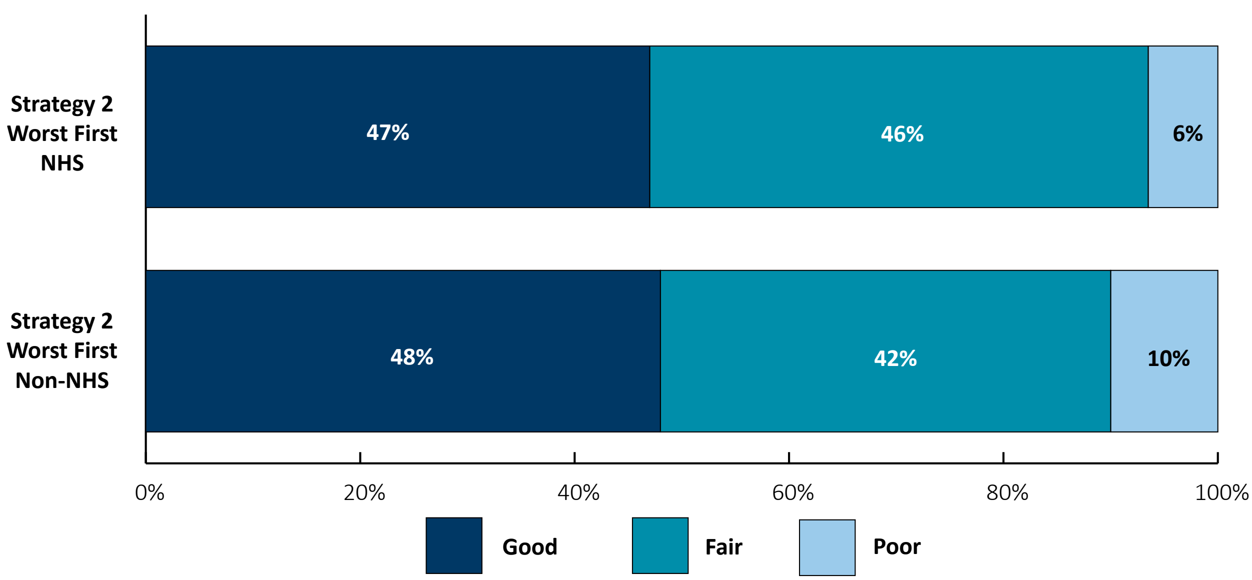


Figure 6-14: Projected 2042 Bridge Conditions––Worst-First Strategy (Unconstrained Budget)



BRIDGE CULVERTS STRATEGIES

Since inventory and condition data for bridge culverts was not available within the BRIM tool, a simplified analysis was conducted for bridge culverts using a Markov modeling approach. Expert judgment was used to estimate the amounts and improvement effects of various treatments. Actual unit cost data from MnDOT financial systems was used to estimate treatment costs.

Two LCP strategies were evaluated for bridge culverts:

- **Strategy #1: Preservation.** This strategy balances investments across the different treatment categories (maintenance, preservation, rehabilitation and replacement).
- **Strategy #2: Minimum Maintenance.** Under this strategy, the impact of only performing routine maintenance actions was evaluated.

Figure 6-15 presents the deterioration models for each LCP strategy evaluated and Figure 6-16 presents the annual treatment distributions and average unit costs.

Figure 6-15: Deterioration Model for Bridge Culverts

Note: Assumed probability of deteriorating from one condition state to another = 50%.

LCP STRATEGY	GOOD TO SATISFACTORY	SATISFACTORY TO FAIR	FAIR TO POOR
Preservation	50	10	10
Minimum Maintenance	41	6	5

Figure 6-16: Annual Treatment Distribution and Average Treatment Costs

Note: Preservation action improves 50% of the culverts acted upon each year by one condition state (e.g., poor to fair, fair to satisfactory) and replacement actions improve 90% of the culverts acted upon to a good condition and the remaining 10% to a fair condition.

TREATMENT	CATEGORY	COST / BRIDGE	% TREATED IN GOOD	% TREATED IN SATISFACTORY	% TREATED IN FAIR	% TREATED IN POOR
Inspection	Inspection	$301	31%	39%	50%	86%
Patching or Repairs	Preservation	$4,500	0.99%	1.39%	0.71%	0.06%
Rehabilitation or Replacement	Rehabilitation/ Replacement	$225,000	0.15%	0.15%	0.15%	0.14%

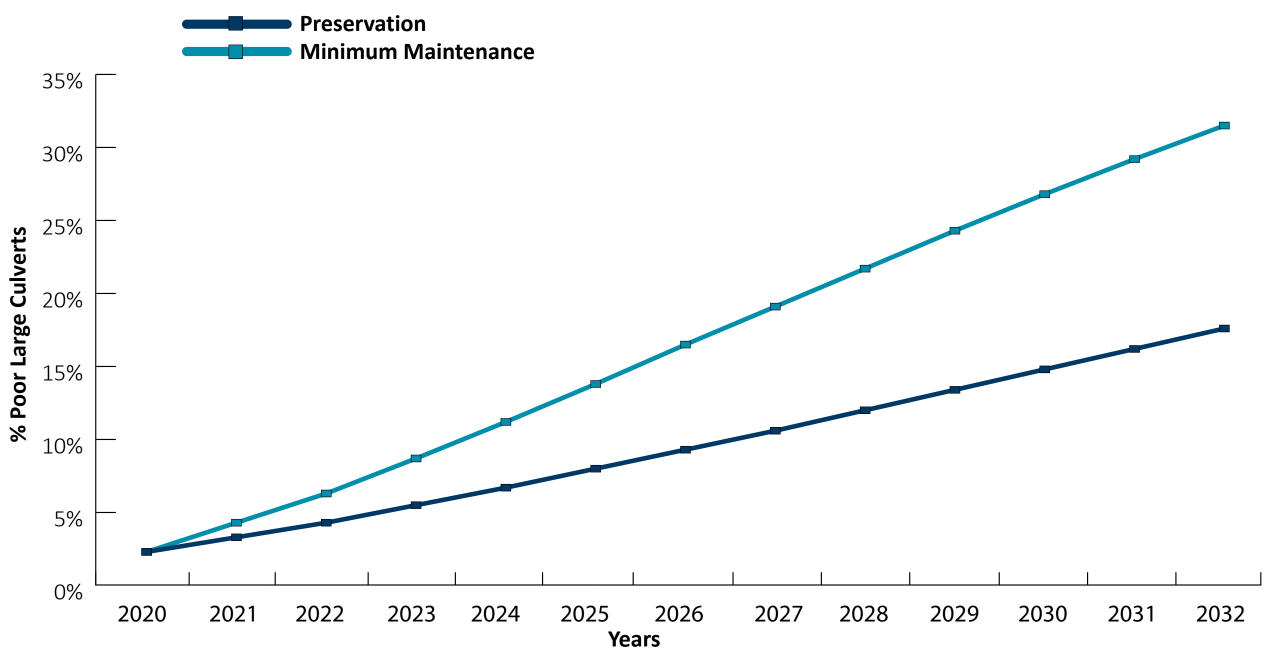
ANALYSIS RESULTS

A 25-year analysis period was used for bridge culverts to determine the funding needs for MnDOT to continue with its existing preservation-focused approach. It compared the performance outcomes to a minimum maintenance strategy, which only allocates funding for routine maintenance actions. Figure 6-17 shows the performance trends (in terms of % poor) for bridge culverts between 2020 and 2032.

The preservation approach will result in approximately 18% of the bridge culverts in poor condition by 2032. In comparison, the minimum maintenance approach will result in over 30% of the bridge culverts in poor condition. The results clearly illustrate the value of the preservation-focused approach that MnDOT has been using to manage the network of large culverts.

The analysis also suggests that between 2023 and 2032, the preservation-focused approach will require an investment of approximately $46.5 million. In comparison, the estimated investment need under the minimum maintenance approach is approximately $9 million. The minimum maintenance approach results in a high risk that poor bridge culverts could fail, results in additional reactive maintenance needs and may have large traffic delay impacts.

Figure 6-17: Performance Trends for Bridge Culverts



OTHER ASSETS

For non-bridge or pavement assets, MnDOT currently does not have a management system with the analytical capabilities to conduct an LCP analysis. In the absence of such a tool, the costs associated with maintaining these assets over the whole life were estimated based on expected treatment cycles and the expert judgment of the asset managers using an advanced spreadsheet tool. Additional information on the approach used for the LCP analysis is provided in Appendix C.

Three treatment strategies were evaluated for each asset:

- **Minimum Maintenance.** Impact of applying routine maintenance treatments and not investing in any preservation or rehabilitation activities.
- **Current Approach.** Impact of following MnDOT's current approach to managing these assets.
- **Desired Approach.** Adjusting MnDOT's current treatment strategies to achieve the 10-year performance target.

Although the analysis was for a more extended period, the results presented in the TAMP are for a 10-year period that coincides with the TAMP planning period.

BUILDINGS

The buildings asset class does not include a life cycle planning process because there is an existing process in the 20-Year Strategic Facilities Asset Management Plan completed in 2021. The life cycle analysis in the facilities plan is different enough from the TAMP process that asset experts decided not to initiate a new life cycle planning process as part of this TAMP.

HIGHWAY CULVERTS

Culverts are inspected on an interval based on condition and risk––new assets are inspected every six years, while those in poor condition may be inspected every year or every other year. MnDOT reports annually the precent of on-time inspections. MnDOT also maintains a culvert inventory, including inspection records and condition information in TAMS. The department has developed treatment decision trees based on culvert size, type, condition and several other "flags," which aids decision making in the life cycle planning of the system of culverts.

Culverts are flushed to remove accumulated debris when sedimentation restricts 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 and, in most cases, have a long life.

Drainage culverts gradually deteriorate, exhibiting corrosion, settlement, deformation, scour from floods, impact damage and debris buildup. One common problem is joint separation, which allows water to flow outside of the culvert, causing the surrounding soil to wash away and creating a void. These voids can potentially cause a local collapse of the roadway above. Figure 6-18 summarizes the list of treatment actions considered for highway culverts along with the estimated distribution of funding from maintenance and capital budgets.

Appendix C provides additional details on the input parameters and analysis assumptions.

Figure 6-18: Treatment Actions for Highway Culverts and Estimated Distribution of Funding from Maintenance and Capital Budgets

TREATMENT	MAINTENANCE FUNDING	CAPITAL FUNDING
Inspection	100%	0%
Cleaning	70%	30%
Reset ends	20%	80%
Joint repair	15%	85%
Pave invert	75%	25%
Replace ends	33%	67%
Slipliner	45%	55%
Cured in-place pipe	0%	100%
Replace-Trench	10%	90%
Replace-Jack	0%	100%

ANALYSIS RESULTS

Figure 6-19 shows the performance trends (percent poor) for highway culverts over 10 years for each LCP strategy investigated. The desired approach results in less than 8% of the assets in poor condition, and the current approach results in almost 16% of the assets in poor condition after 10 years. In comparison, the minimum maintenance approach will result in approximately 20% of the assets in poor condition. Due to the low level of service from this approach, the minimum maintenance approach was not included in further analysis. To see how the desired and current approach treatments differ, see Appendix C.

The distribution of conditions over the 10-year performance period for highway culverts is shown in Figure 6-20. The figure illustrates the benefits associated with the desired strategy.

Figure 6-19: 10-Year Performance Trends for Highway Culverts

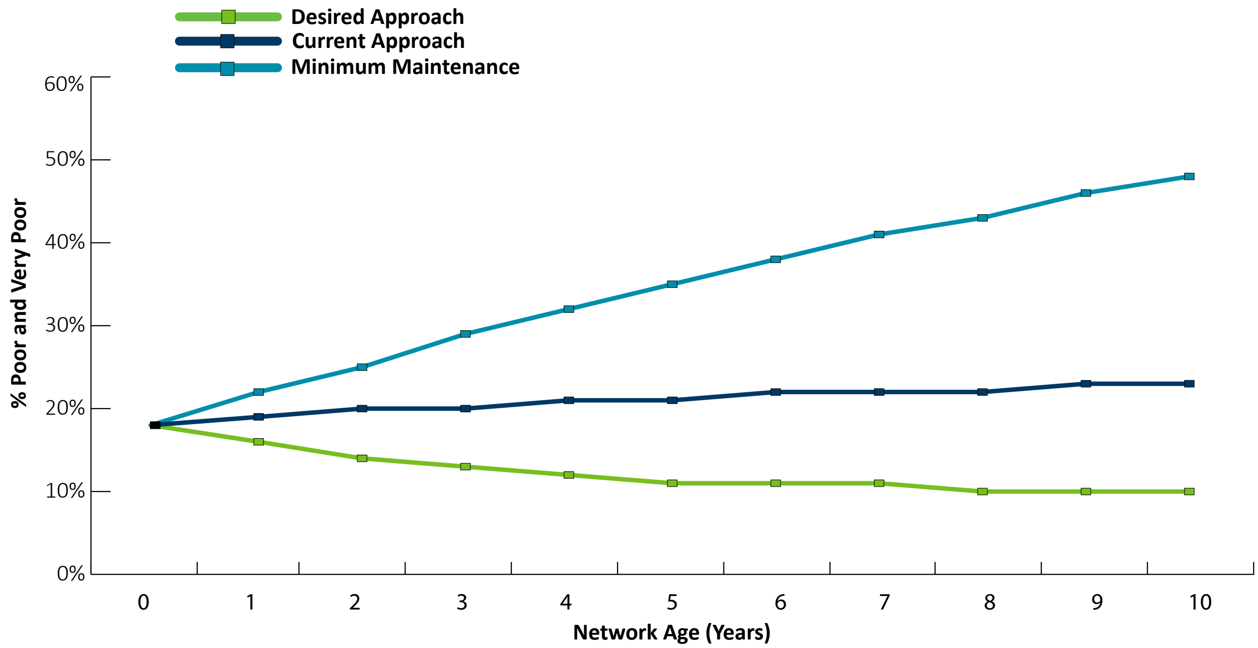
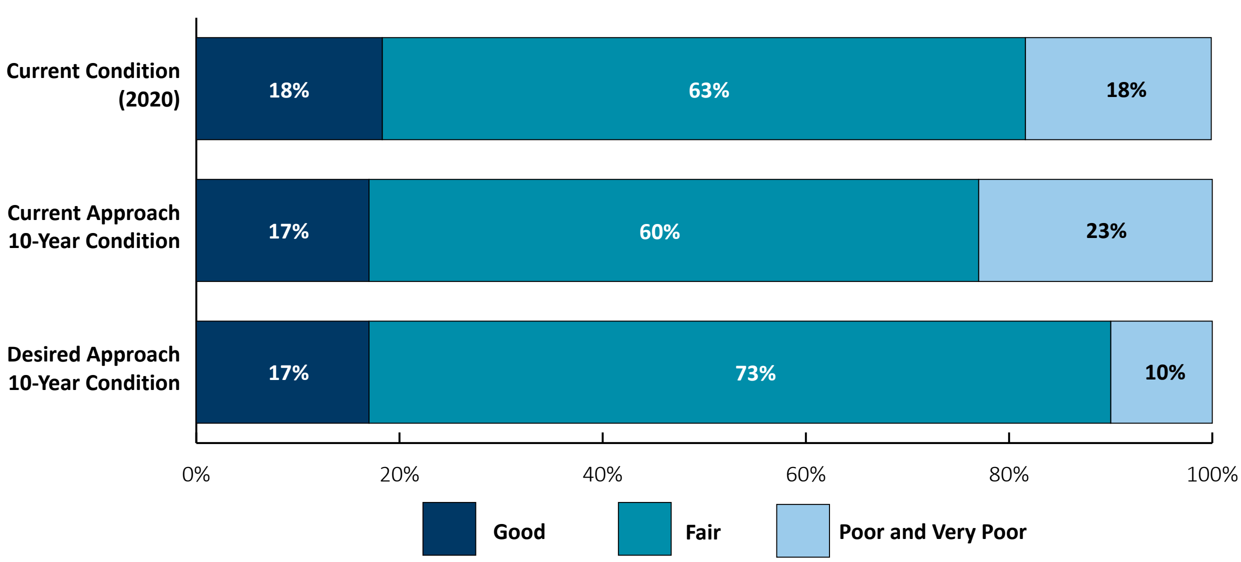


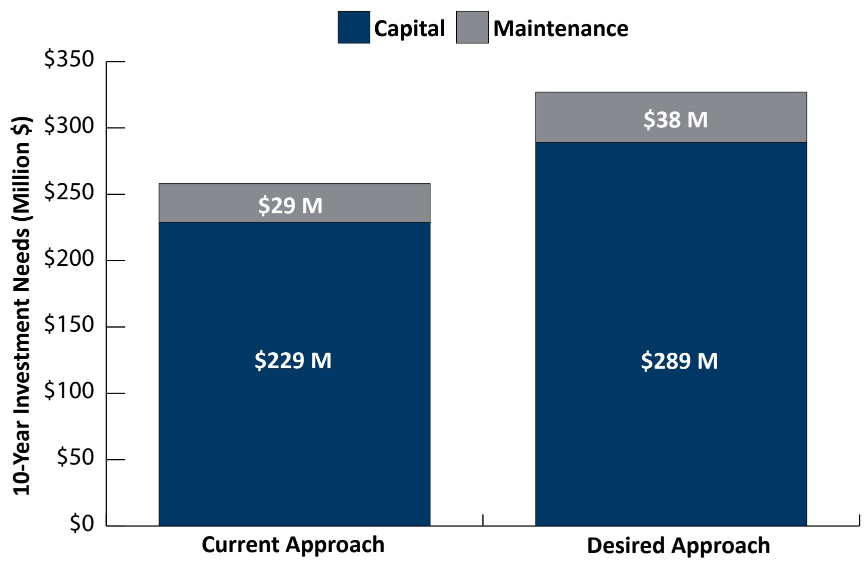
Figure 6-21 presents the investment needs associated with the current and desired approaches. It shows the increased level of investment needed for both the maintenance and capital budgets. The maintenance investment need for the desired approach is approximately 31% more than the current approach's

Figure 6-20: Comparison of Current and 10-Year Projected Conditions for Highway Culverts



maintenance investment need. Under the desired approach, the capital investment need is approximately 26% more than the capital investment need under the current approach. The increase in maintenance and capital investments will help MnDOT meet its desired performance target of no more than 10% of the highway culverts in poor condition. The increase in maintenance and capital spending is due to the increased frequency of fixes such as resetting ends, joint repair, end replacement and slipliners. In the context of highway culverts, most fixes share maintenance and capital dollars.

Figure 6-21: 10-Year Investment Needs for Highway Culverts



TAKEAWAYS

- The LCP analysis estimates that highway culverts need an additional $69 million to reach the desired performance target by 2032 (10% poor). The increased investment would primarily fund capital costs such as reset ends, joint repair, cured in-place pipe and trench replacement.
- Currently, 82% of the inventory is in fair to very poor condition, which explains the need for more substantial capital improvements.

DEEP STORMWATER TUNNELS

MnDOT maintains an inventory of eight deep stormwater tunnels that range in length from 0.2 to 4.6 miles, which adds up to 73,101 linear feet or nearly 14 total miles. All eight tunnels have had detailed inspection studies, identifying specific conditions and repair needs. Some deep stormwater tunnels are inspected and repaired in conjunction with the cities of Saint Paul and Minneapolis. Typical repairs consist of sealing tunnel cracks and fractures and grouting the annular space between the tunnel concrete liner and the supporting sandstone layer where voids have developed. MnDOT has made substantial investments in preventive maintenance over the last few years. Figure 6-22 summarizes the list of treatment actions considered for deep stormwater tunnels along with the estimated distribution of funding from maintenance and capital budgets.

Figure 6-22: Treatment Actions for Deep Stormwater Tunnels and Estimated Distribution of Funding from Maintenance and Capital Budgets

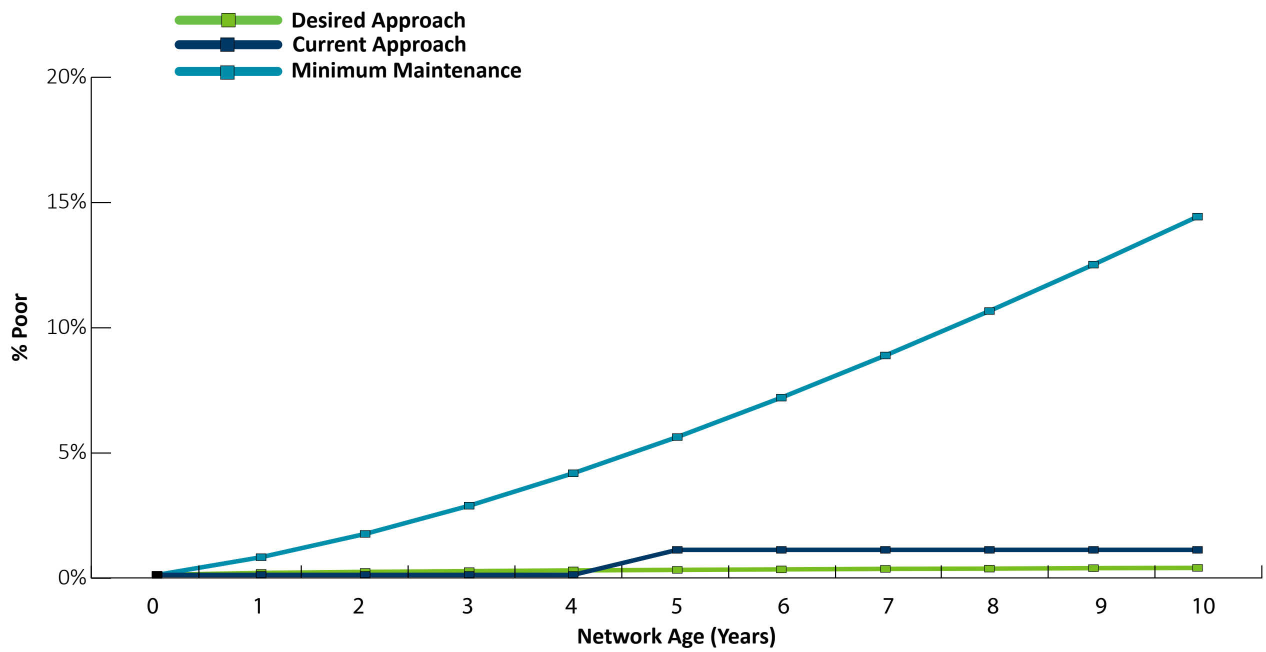
TREATMENT	MAINTENANCE FUNDING	CAPITAL FUNDING
Inspection	0%	100%
Routine Maintenance	0%	100%
Repairs (Fill voids behind tunnels, seal cracks)	0%	100%
Minor Rehab (Steel band installation)	0%	100%
Major Rehab (Replacement)	0%	100%

Appendix C provides additional details on the input parameters and analysis assumptions.

ANALYSIS RESULTS

Figure 6-23 shows the performance trends, in terms of percent poor (significant defects and very significant defects), for deep stormwater tunnels over 10 years for each LCP strategy investigated. The desired approach and the current approach result in less than 1% of the assets in poor condition after 10 years. In comparison, the minimum maintenance approach results in almost 15% of the assets being in poor condition. Due to the low level of service from this approach, it was not considered further. For the current and desired approaches, the project asset condition remains stable over the 10-year period. To see how the desired and current approach treatments differ, see Appendix C.

Figure 6-23: 10-Year Performance Trends for Deep Stormwater Tunnels



The distribution of conditions over the 10-year performance period for deep stormwater tunnels is shown in Figure 6-24. The figure shows very similar conditions between the current and desired approaches, but as Figure 6-25 illustrates, the desired approach is more expensive over the 10-year period.

Figure 6-24: Comparison of Current and 10-Year Projected Conditions for Deep Stormwater Tunnels

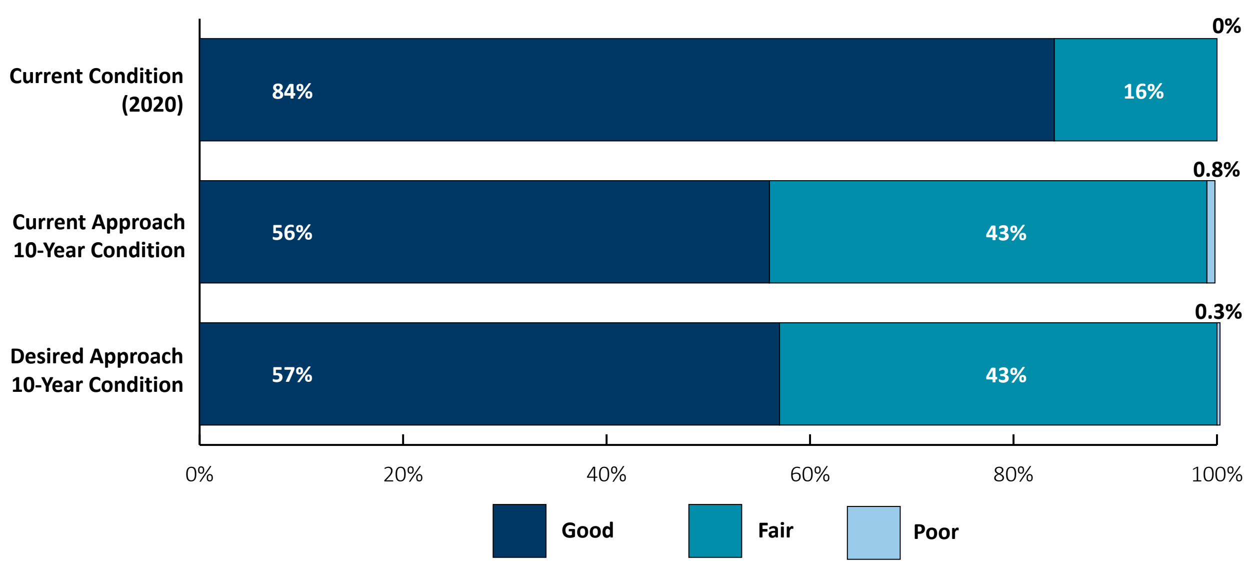
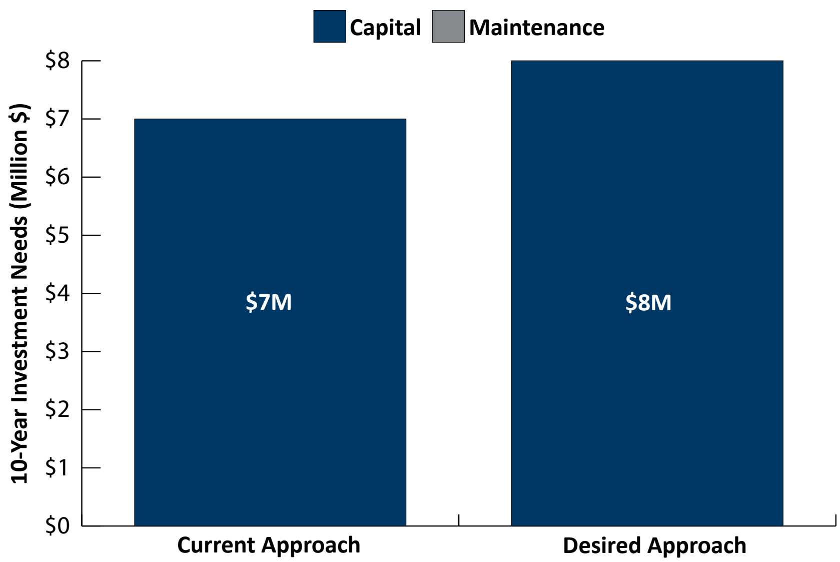


Figure 6-25 presents the investment needs associated with the current and desired approaches. Since all the funding for deep stormwater tunnels comes from the capital budget, maintenance investment needs are not identified in Figure 6-24. The capital investment need under the desired approach is approximately 14% higher than the current approach. The increase in capital spending is attributed to a strategic increase in routine maintenance, repairs and minor/major rehabilitation. The current and desired approaches meet MnDOT's performance target of no more than 10% of the deep stormwater tunnels in poor condition.

Figure 6-25: 10-Year Investment Needs for Deep Stormwater Tunnels



TAKEAWAYS

- Most of the deep stormwater tunnel system is in good condition, which lasts 14 years on average before transitioning to fair condition. Since a large portion of the network is in good condition, investments over the next 10 years will maintain current asset conditions and exceed the established performance target.
- On the surface, the condition outcome appears optimistic, but it does not reflect the need for modernization and resilience. There is a need to increase tunnel capacity to handle stormwater runoff and expected increased rainfall frequency and intensity.

INTELLIGENT TRANSPORTATION SYSTEMS

MnDOT conducted a life cycle planning analysis for seven different ITS assets. Each asset has different life cycles, inspection frequencies and maintenance activities. A summary of typical treatment actions performed for each asset is presented in Figure 6-26.

Figure 6-26: ITS Infrastructure Assets and Typical Treatment ActionsYear

Investment Needs for Deep Stormwater Tunnels

ITS ASSET	TYPICAL TREATMENT ACTIONS
Fiber Network Shelters	Routine, Preventive Maintenance, and Minor Rehabilitation Actions: Filter change, fan checks and replacement, power supply check and replacements, infestation and leak checks, debris removal. Major Rehabilitation: Power supply replacement, fan replacement, HVAC system maintenance. Replacement: Shelter and foundation replacement
Traffic Management System Cabinets	Routine and Preventive Maintenance: Filter replacement, general cleaning, inspection. Minor Rehabilitation: Fan replacement. Major Rehabilitation: Door and lock replacement. Replacement: Cabinet replacement
Dynamic Message Signs	Routine and Preventive Maintenance: Filter change, fan check, pixel board and power supply check, infestation and leak checks, debris removal. Minor Rehabilitation: Fan replacement, power supply replacement. Major Rehabilitation: Pixel board replacement. Replacement: Walk-in DMS and post-mounted DMS installation
Traffic Monitoring Cameras	Routine and Preventive Maintenance: Tilt camera up (to let rain wash the lens of camera). Minor Rehabilitation: Wiper blade replacement. Major Rehabilitation: Repair of internal and external camera components. Replacement: Replacement or upgrade of camera
E-ZPass Readers	Routine and Preventive Maintenance: Annual inspection (five years after installation) to ensure mounting brackets on antennae are in good condition. Minor Rehabilitation: N/A. Major Rehabilitation: N/A. Replacement: Complete replacement of device
Reversible Road Gates	Routine and Preventive Maintenance: Lubrication, hydraulic oil draining and replacement. Minor Rehabilitation: Flasher unit, orange flag replacement. Major Rehabilitation: Hydraulic pump and arm replacement. Replacement: Complete replacement
Ramp Meters	Routine and Preventive Maintenance: None. Minor Rehabilitation: LED bulb replacement. Major Rehabilitation: New indicators (signal body). Replacement: Complete replacement
Fiber Communication Network	Routine and Preventive Maintenance: None. Minor Rehabilitation: Splice in connectors. Major Rehabilitation: Fixing severed cable. Replacement: Complete replacement
Traffic Detection	Routine and Preventive Maintenance: None. Minor Rehabilitation: Splice (loops); recalibration (radar). Major Rehabilitation: Wire pulls (loops); new eletrical wires (radars). Replacement: Complete replacement

Figure 6-27 summarizes the estimated distribution of funding from maintenance and capital budgets for each treatment category.

Figure 6-27: Treatment Actions for ITS Infrastructure Assets and Estimated Distribution of Funding from Maintenance and Capital Budgets

**For ramp meters, 100% funding is from capital funding.*
***For traffic monitoring cameras, the funding is distributed equally between maintenance and capital funding*

TREATMENT	MAINTENANCE FUNDING	CAPITAL FUNDING
Routine Maintenance	100%	0%
Preventive Maintenance	100%	0%
Minor Rehabilitation	100%	0%
Major Rehabilitation*	100%	0%
Replacement**	0%	100%

Appendix C provides additional details on the input parameters and analysis assumptions.

ANALYSIS RESULTS

Figure 6-28 shows the distribution of conditions over the 10-year period for each ITS asset for the current and desired approaches. The results of the minimum maintenance approach are not presented due to the low level of service over the life of the asset. To see how the desired and current approach treatments differ, see Appendix C.

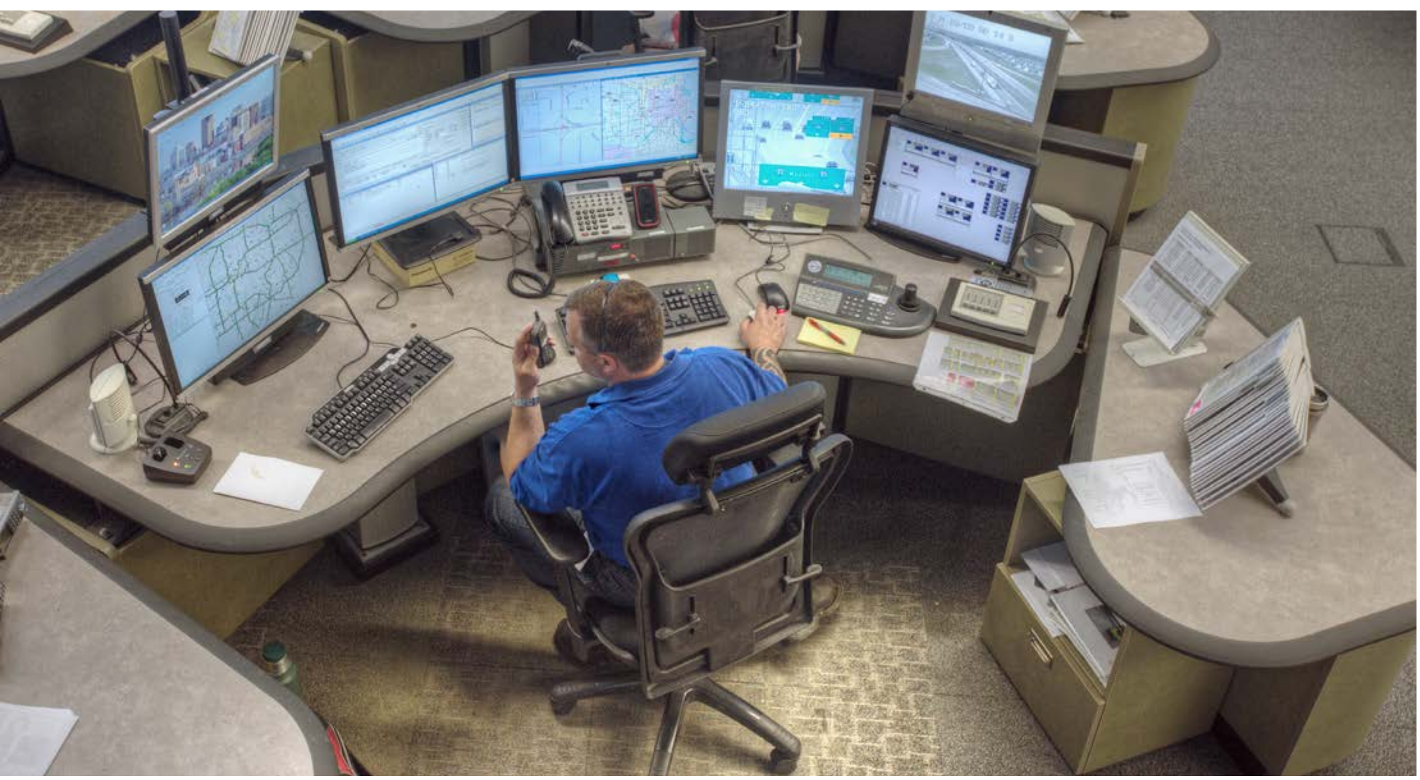
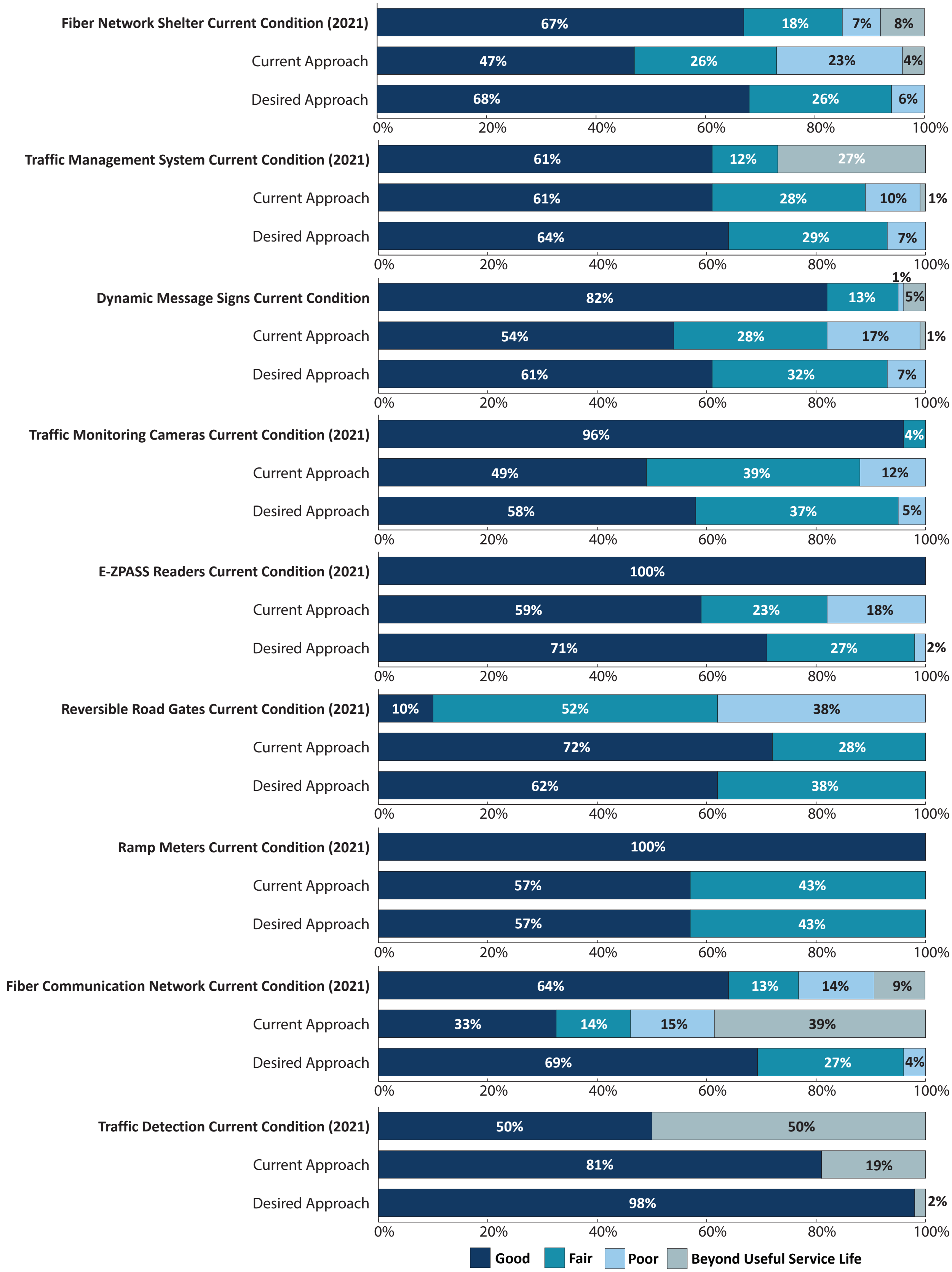


Figure 6-28: Comparison of Current and 10-Year Projected Conditions for ITS



Some of the key observations noted for each asset are summarized below.

- **Fiber Network Shelters:** The desired approach results in no assets in beyond useful service life condition and 6% of assets in poor condition after 10 years. The current approach results in approximately 4% of the assets beyond useful service life and over 23% in poor condition after 10 years.
- **Traffic Management System Cabinets:** The desired approach results in no assets beyond useful service life and 7% of assets in poor condition after 10 years. The current approach results in less than 1% of assets in beyond useful service life and 10% in poor condition after 10 years.
- **Dynamic Message Signs:** The desired approach results in no assets in beyond useful service life and 7% of assets in poor condition after 10 years. The current approach results in approximately 1% of the assets in beyond useful service life and 17% in poor condition after 10 years.
- **Traffic Monitoring Cameras:** The desired approach results in no assets beyond useful service life and 5% of assets in poor condition after 10 years. The current approach results in no assets in beyond useful service life and 12% in poor condition after 10 years.
- **E-ZPass Readers:** The desired approach results in no assets beyond useful service life and 2% of assets in poor condition after 10 years. The current approach results in no assets in beyond useful service life and 18% of assets in poor condition after 10 years.
- **Reversible Road Gates:** The desired and current approaches result in no assets in beyond useful service life or poor conditions after 10 years.
- **Ramp Meters:** The desired and current approaches result in no assets in poor condition after 10 years.
- **Fiber communication network:** The desired approach results in no assets beyond useful service life and 4% of assets in poor condition after 10 years. The current approach results in 38.6% of assets beyond useful service life and 15.3% of assets in poor condition after 10 years.
- **Traffic Detection:** The desired approach results in 2% of assets beyond useful service life after 10 years. The current approach results in 19% of assets beyond useful service life after 10 years.

Figures 6-29, 6-30 and 6-31 present the investment needs associated with the current and desired approaches for all ITS assets. Following are the observations noted for each ITS asset.

- **Fiber Network Shelters:** The maintenance investment need for both approaches is similar. The capital investment need for the current approach is 11% higher than the desired approach. The increase is attributed to shelter replacements.
- **Traffic Management System Cabinets:** The maintenance investment need under the desired approach is 69% higher than the current approach and the capital investment need under the desired approach is 44% higher compared to the current approach. The maintenance increase is attributed to doubling the frequency of routine maintenance and a slight increase in minor rehabilitation for cabinets in good condition. Conversely, the capital increase is tied to cabinet replacements in poor condition and beyond useful service life.

- **Dynamic Message Signs:** The maintenance investment need under the desired approach is 28% higher than the current approach. The capital investment need under the desired approach is higher by 19% than the current approach. The maintenance increase is tied to doubling the frequency of routine and preventive maintenance under all conditions, including signs beyond useful service life. The capital increase is due to increasing the annual percentage of signs replaced beyond useful service life from 90% to 100%.
- **Traffic Monitoring Cameras:** The capital investment needs for both approaches are very similar with the desired approach providing lower need. The maintenance investment need under the desired approach is approximately two times higher compared to the current approach. This increase is due to the inclusion of annual routine maintenance in the desired approach.
- **E-ZPass Readers:** The investment needs under the current and desired approaches are very similar. The desired approach includes a 10-year replacement cycle for assets in poor condition.
- **Reversible Road Gates:** The maintenance investment need under the desired approach is 20% higher than the current approach. The capital investment need under the desired approach is approximately three times higher than the current approach. Minor and major rehabilitation actions are performed more frequently under the desired approach.
- **Ramp Meters:** The investment needs are similar for both the current and desired approaches.
- **Fiber communication network:** The maintenance investment need under the desired approach is 10 time higher than the current approach. The capital investment need under the desired approach is approximately three times higher than the current approach. The increase is due to the increased number of annual replacements needed to increase to meet the condition target.
- **Traffic Detectors:** The maintenance investment need under the desired approach is 33% higher than the current approach. The capital investment need under the desired approach is approximately 40% higher than the current approach. The increase is due to the increased number of annual replacements needed to increase to meet the condition target. Both approaches would be higher but RTMC is in the process of replacing loops detectors (which cover a single lane) with radar detectors (which cover multiple lanes). This will reduce the number of traffic detector systems over the next 10 years.

ITS FUNDING TO IMPLEMENT CURRENT APPROACH

The investment needed to implement the current approach to manage ITS assets depends on yearly budgets, end-of-year/one-time funding, and replacements as a part of roadway reconstruction projects. The current approach in Figures 6-29 to 6-31 assume these funding sources will continue. The planned investments in **Chapter 4: Asset Management Performance Measures, Targets and Performance Gaps** do not consider these funding sources.

Figure 6-29: 10-year Investment Needs for Fiber Network Shelters, TMS Cabinets, DMS and Traffic Monitoring Cameras

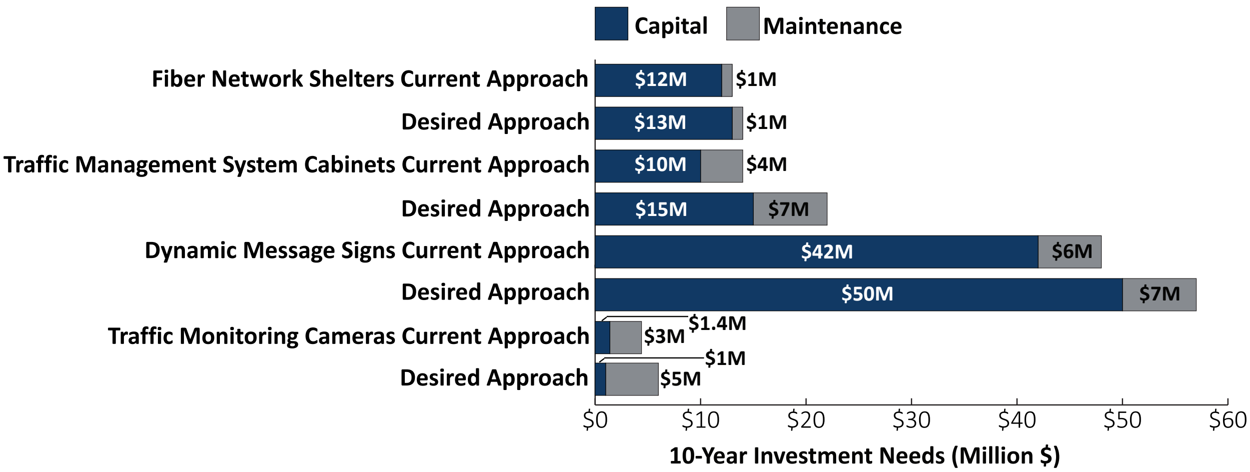


Figure 6-30: 10-year Investment Needs for E-ZPass Readers, Reversible Road Gates and Ramp Meters

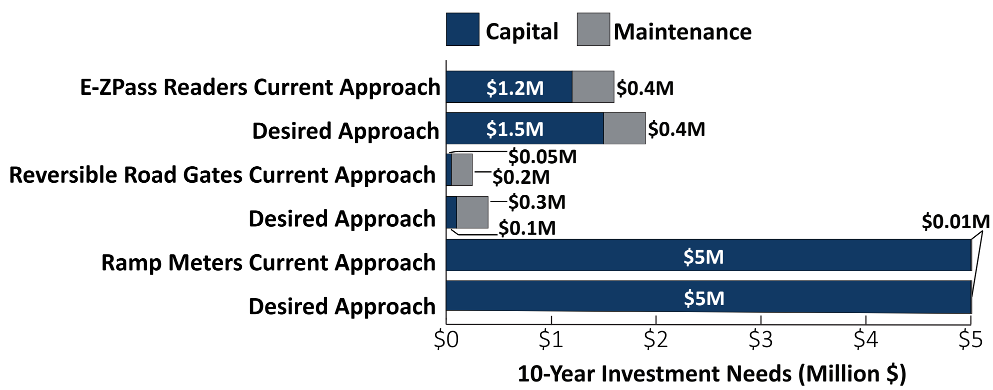
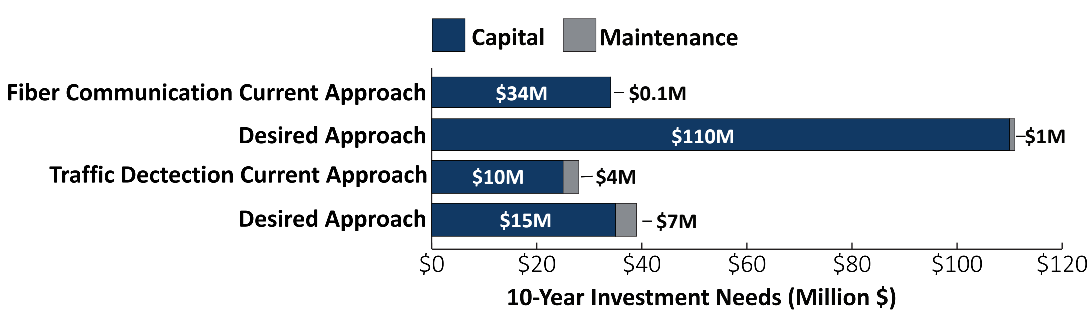


Figure 6-31: 10-year Investment Needs for Fiber Communication Network and Traffic Detectors



TAKEAWAYS

- ITS infrastructure continues to be a developing asset class. Technology shifts are a more significant concern than the age of the asset and may impact the practical service life of ITS assets more than condition.
- The current approach used to manage ITS assets shows the value of incorporating routine and preventive maintenance actions to extend the expected service life. There may be added service life for some ITS assets by increasing routine or preventive maintenance from once a year to twice a year and completing rehabilitation treatments sooner.
- The desired approach requires more replacement of assets when in poor condition before they reach beyond their useful service life.

NOISE WALLS

Noise walls are inspected on a 10-year cycle, with the last inventory and inspection completed in 2019. Out-of-cycle inspections are conducted if a serious defect that requires more frequent monitoring is found. Reactive maintenance activities are performed annually on an as-needed basis. Rehabilitation activities include minor concrete panel repair or wood re-planking. Figure 6-32 summarizes the list of treatment actions considered for noise walls along with the estimated distribution of funding from maintenance and capital budgets.

Figure 6-32: Treatment Actions for Noise Walls and Estimated Distribution of Funding from Maintenance and Capital Budgets

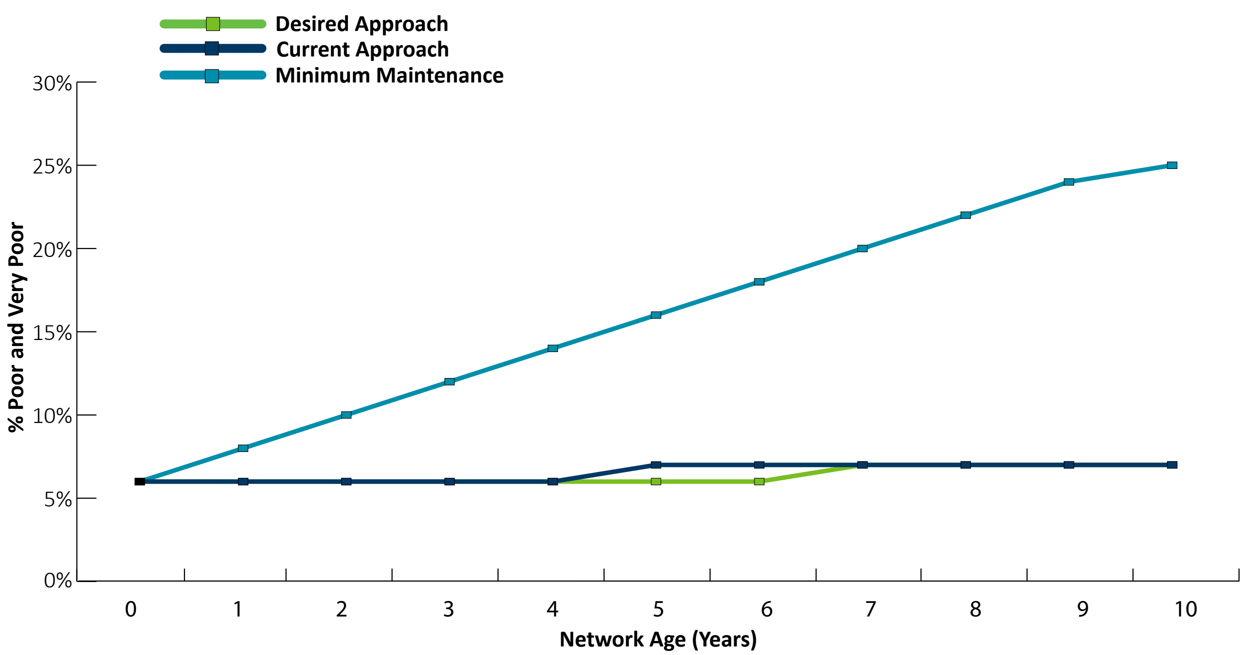
TREATMENT	MAINTENANCE FUNDING	CAPITAL FUNDING
Structural Inspection	0%	100%
Reactive Maintenance	100%	0%
Out of Cycle Inspection	100%	0%
Re-Planking (Wood Panel)/ Minor Rehab (Concrete)	0%	100%
Splash Zone Sealing	0%	100%
Replacement	0%	100%

Appendix C provides additional details on the input parameters and analysis assumptions.

ANALYSIS RESULTS

Figure 6-33 shows the performance trends (percent poor) for wood panel noise walls over 10 years for each LCP strategy investigated. Both the current and desired approaches result in nearly 7% of the assets in poor condition after 10 years. In comparison, the minimum maintenance approach results in over 25% of the assets in poor condition. Due to the low level of service from this approach, it was not considered further. To see how the desired and current approach treatments differ, see Appendix C.

Figure 6-33: 10-Year Performance Trends for Wood Panel Noise Walls



The distribution of conditions over the 10-year performance period for wood panel noise walls is shown in Figure 6-34. The performance outcomes from the current and desired strategies are very similar.

Figure 6-34: Comparison of Current and 10-Year Projected Conditions for Wood Panel Noise Walls

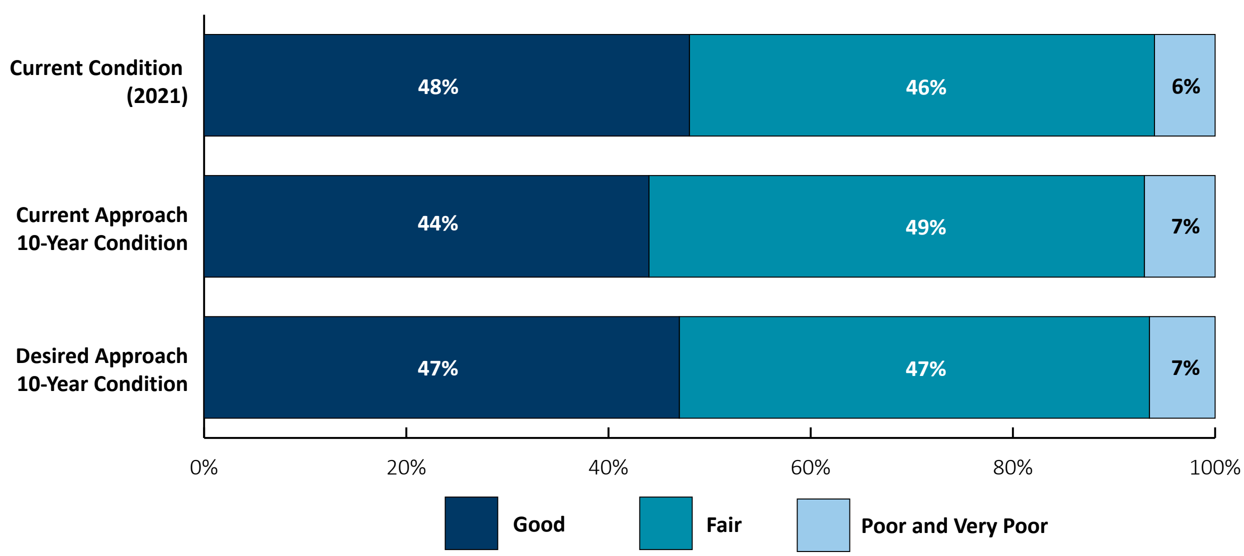


Figure 6-35 presents the investment needs of the current and desired approaches for wood panel noise walls. The maintenance need is the same for both the current and desired approaches. However, the capital investment under the desired approach is 20% higher than the current approach. This increase is not necessary for meeting the target but would improve the percentage of walls in good and fair condition.

Figure 6-35: 10-Year Investment Needs for Wood Panel Noise Walls

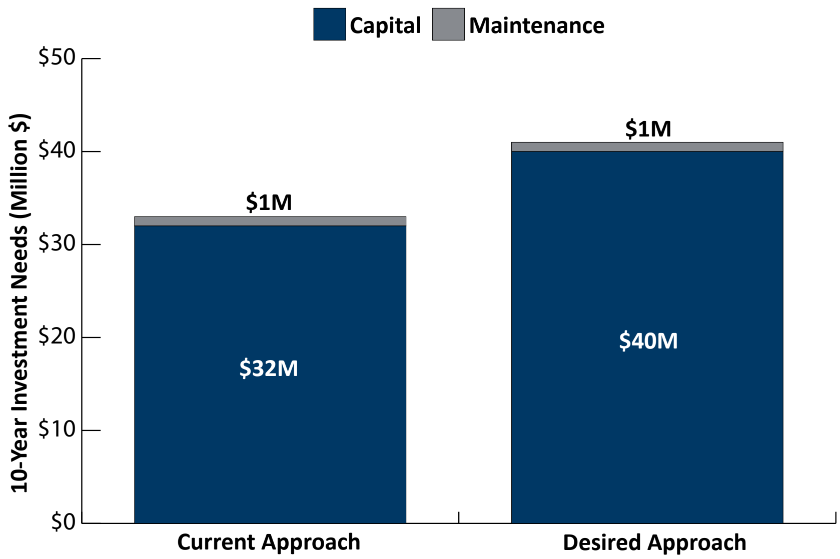
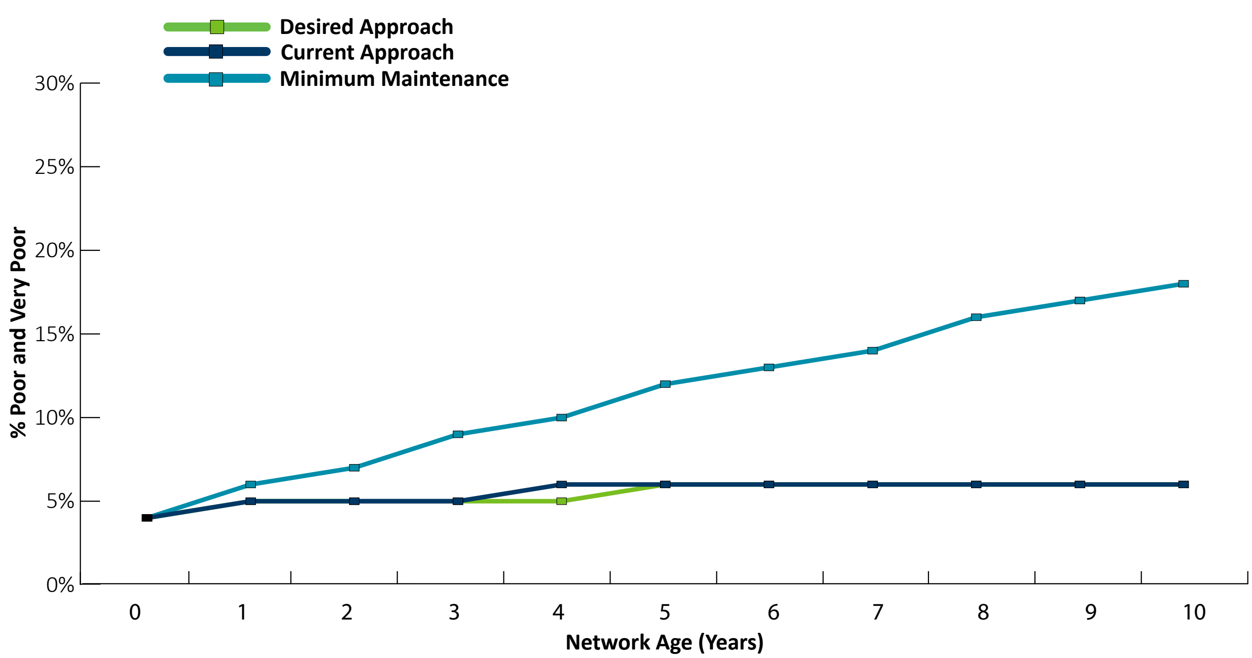


Figure 6-36 shows the performance trends (percent poor) for concrete noise walls over 10 years for each LCP strategy investigated. Both the current and desired approaches result in approximately 6% of the assets in poor condition after 10 years. In comparison, the minimum maintenance approach will result in over 18% of the assets in poor condition. Due to the low level of service from this approach, it was not considered further.

Figure 6-36: 10-Year Performance Trends for Concrete Noise Walls



The distribution of conditions over the 10-year performance period for concrete noise walls is shown in Figure 6-37. The performance outcomes from the current and desired strategies are very similar.

Figure 6-37: Comparison of Current and 10-Year Projected Conditions for Concrete Noise Walls

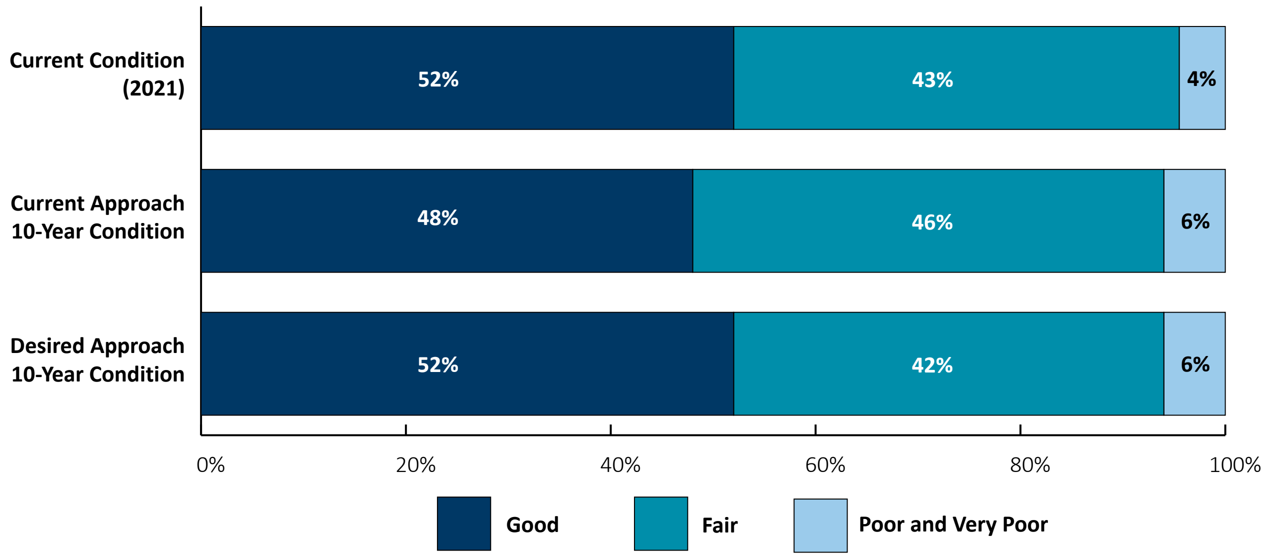
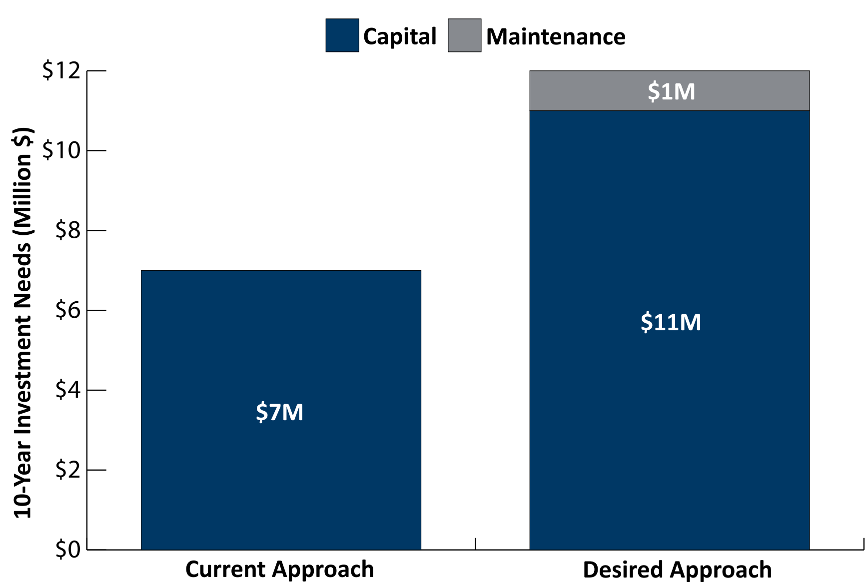


Figure 6-38 presents the investment needs of the current and desired approaches for concrete noise walls. Currently, MnDOT is not performing any maintenance (reactive maintenance and out-of-cycle inspection) on concrete noise walls; hence, there are no maintenance costs reported for the current approach. The capital investment need under the desired approach is almost 60% higher than the current approach. This additional investment is associated with the splash zone sealing treatment under the desired strategy for noise walls in fair or worse condition. While the investments in splash zone sealing under the desired strategy may not significantly impact 10-year condition outcomes, it is expected to extend the overall service life of noise walls. The increase in maintenance spending covers minimal reactive maintenance and out-of-cycle inspections.

Figure 6-38: 10-Year Investment Needs for Concrete Panel Noise Walls



TAKEAWAYS

- Both wood and concrete noise walls will benefit from an increased frequency of out-of-cycle inspections.
- Investing in splash zone sealing for noise walls in fair or worse condition is expected to extend the service life of concrete noise walls.

OVERHEAD SIGN STRUCTURES

MnDOT uses a uniform statewide overhead sign structure inspection process. Typical reactive maintenance activities performed on overhead sign structures include tightening nuts and removing grout. Minor rehabilitation activities performed include re-grading footing, replacing welds, removing catwalks/lighting and replacing individual elements. Most of the responsibility for inspecting and maintaining these structures falls on district staff, and MnDOT has developed cost-recording protocols to improve the cost data for these assets. Figure 6-39 summarizes the list of treatment actions considered for overhead sign structures along with the estimated distribution of funding from maintenance and capital budgets.

Figure 6-39: Treatment Actions for Overhead Sign Structures and Estimated Distribution of Funding from Maintenance and Capital Budgets

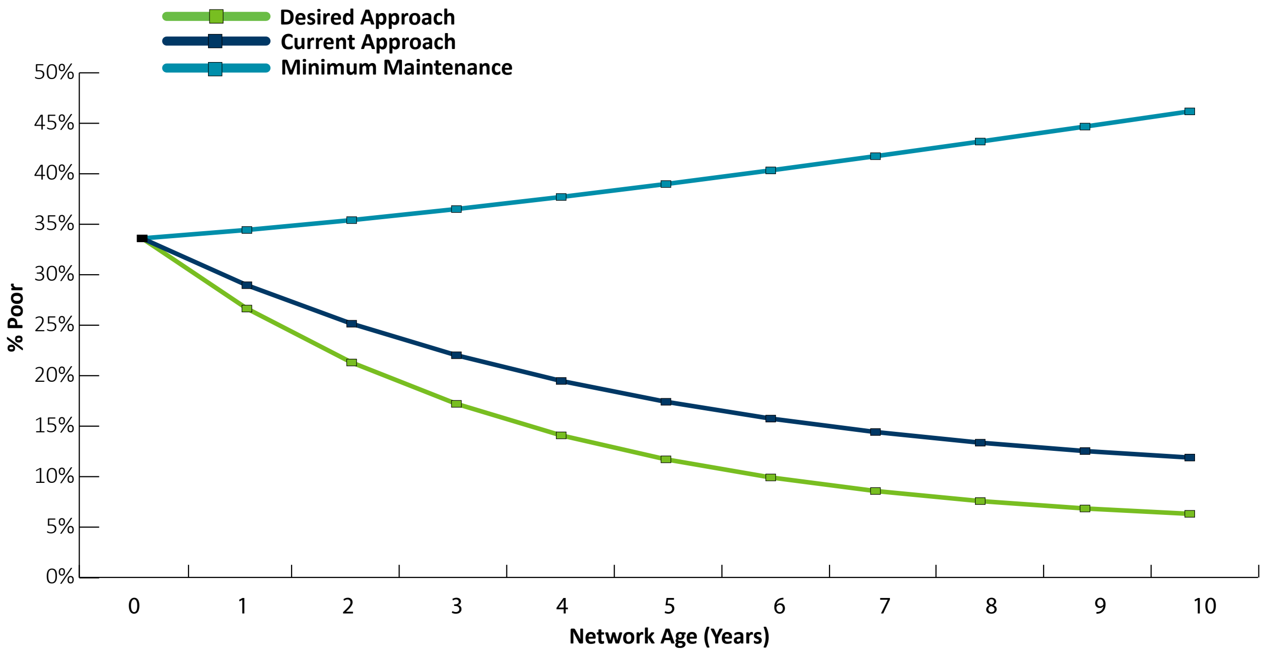
TREATMENT	MAINTENANCE FUNDING	CAPITAL FUNDING
Reactive Maintenance	100%	0%
Structural Inspection	100%	0%
Out-of-cycle inspection	100%	0%
Tighten Nuts	100%	0%
Major rehabilitation	0%	100%
Replacement	0%	100%

Appendix C provides additional details on the input parameters and analysis assumptions.

ANALYSIS RESULTS

Figure 6-39 shows the performance trends (in terms of percent poor) for overhead sign structures over 10 years for each LCP strategy investigated. The desired approach results in approximately 6% of overhead signs in poor condition and the current approach results in almost 12% in poor condition after 10 years. In comparison, the minimum maintenance approach will result in over 45% in poor condition. Due to the low level of service from this approach, it was not considered further. To see how the desired and current approach treatments differ, see Appendix C.

Figure 6-40: 10-Year Performance Trends for Overhead Sign Structures



The distribution of conditions over the 10-year performance period for overhead sign structures is shown in Figure 6-41. The figure reflects slightly better conditions under the desired approach than with the current approach.

Figure 6-41: Comparison of Current and 10-Year Projected Conditions for Overhead Sign Structures

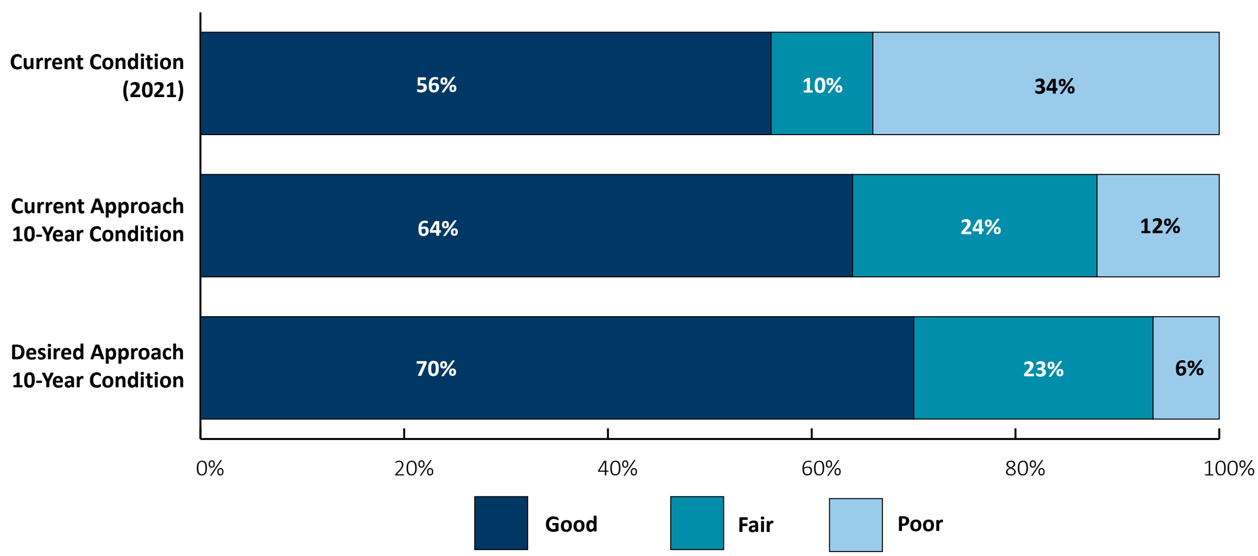
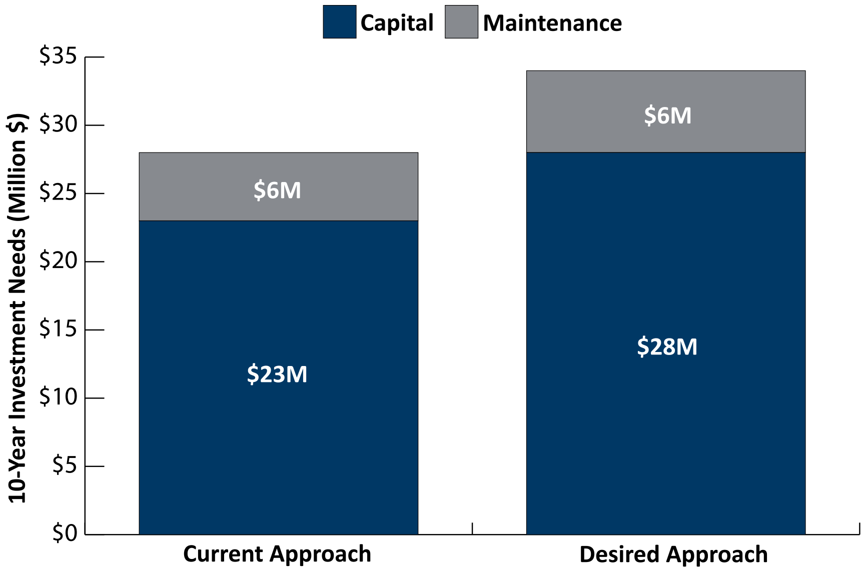


Figure 6-42 presents the investment needs associated with the current and desired approaches. The maintenance and capital investment needs for the desired approach is approximately 20% higher than the current approach. Additional investments under the desired approach include a marginal increase in the frequency of out-of-cycle inspections, tightening nuts for maintenance and an increase in major rehabilitation and replacements. This investment will help MnDOT meet the desired performance target of no more than 10% of the assets in poor condition.

Figure 6-42: 10-Year Investment Needs for Overhead Sign Structures



TAKEAWAYS

The LCP process highlighted that overhead signs structures would benefit from an increase in out-of-cycle inspections to help proactively identify critical issues that are emerging.

PEDESTRIAN INFRASTRUCTURE

Pedestrian infrastructure includes two sub-asset classes: curb ramps and sidewalks. MnDOT inspects and maintains its entire pedestrian infrastructure inventory. The frequency of local inspections can vary but are generally completed every five years. MnDOT schedules inspections every 10 years, with the last full inspection conducted in 2015.

The pedestrian infrastructure network has two condition categories: "Compliant" and "Non-Compliant." The compliance rating is based on Federal ADA compliance standards. A sidewalk is substantially compliant if its cross-slope is less than 3%. Additionally, the full compliance threshold requires cross slopes to be 2% or less. There are limitations in preventing compliant curb ramps and sidewalks from being constructed, such as existing topography, right-of-way requirements, historic preservation and maximum extent feasibility. Some other reasons for non-compliance could be attributed to natural events and wear-and-tear over the asset's lifecycle. Figure 6-43 summarizes the treatment actions considered for curb ramps and sidewalks and the estimated distribution of funding from maintenance and capital budgets.

Figure 6-43: Treatment Actions for Pedestrian Facilities and Estimated Distribution of Funding from Maintenance and Capital Budgets

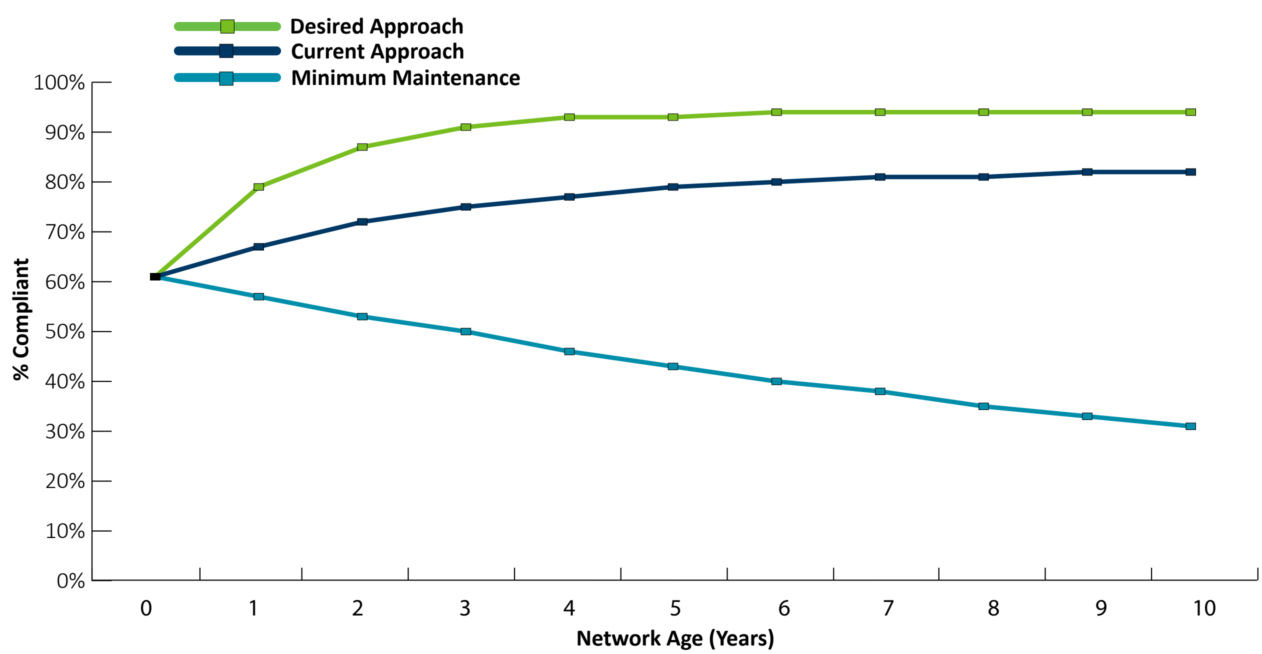
TREATMENT	MAINTENANCE FUNDING	CAPITAL FUNDING
Inspection	100%	0%
Grinding	100%	0%
Slab Jacking	100%	0%
Vegetation Removal	100%	0%
Major Rehabilitation (Panel Replacement - Sidewalks Only)	0%	100%
Complete Replacement	0%	100%

Appendix C provides additional details on the input parameters and analysis assumptions.

ANALYSIS RESULTS

Figure 6-44 shows the performance trends (in terms of percent compliant) for curb ramps over 10 years for each LCP strategy investigated. The desired approach results in more than 94% of curb ramps in compliant condition. The current approach results in almost 82% of the assets in a compliant condition after 10 years. In comparison, the minimum maintenance approach will result in only 30% of the assets in compliant condition. Due to the low level of service from this approach, it was not considered further. For the current approach, the fraction of assets in a compliant condition increases over the first four years and then plateaus around 80% compliant. Conditions in the desired approach increase rapidly over the first four years and plateaus as it nears the target. To see how the desired and current approach treatments differ, see Appendix C.

Figure 6-44: 10-Year Performance Trends for Curb Ramps



A snapshot of the 10-year performance for curb ramps is shown in Figure 6-45, and Figure 6-46 presents the investment needs associated with the current and desired approaches.

Figure 6-45: Comparison of Current and 10-Year Projected Conditions for Curb Ramps

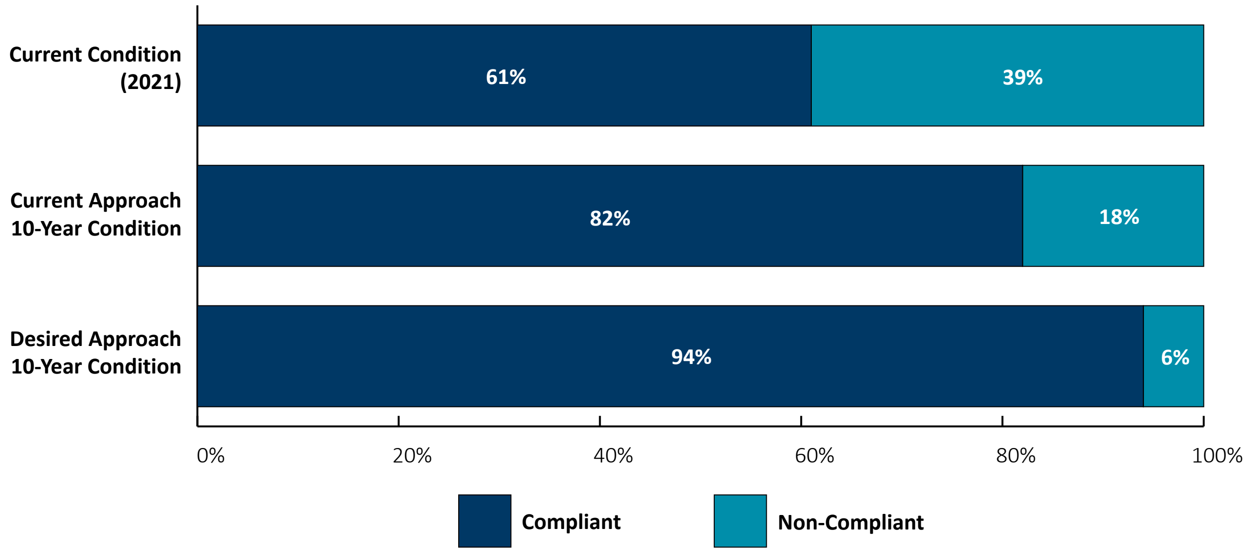
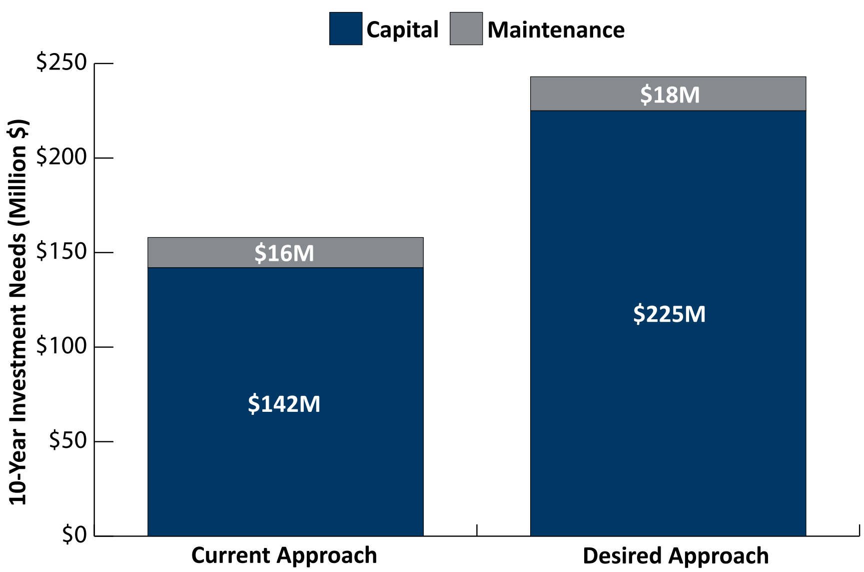


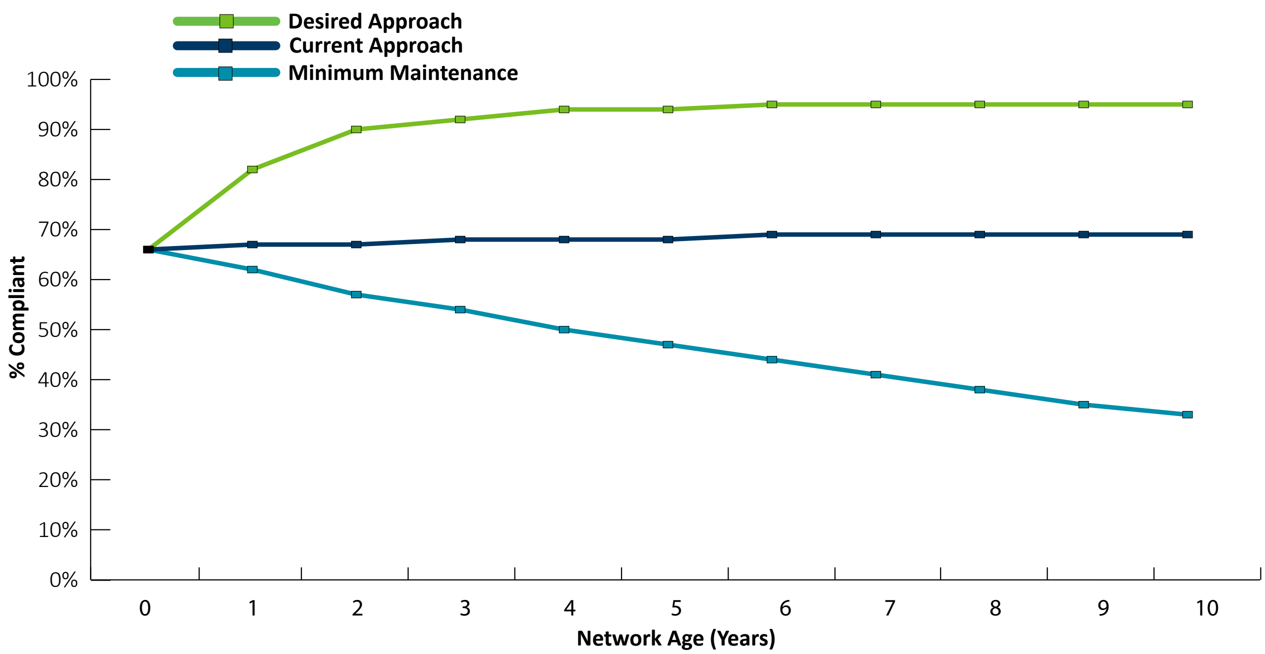
Figure 6-46: 10-Year Investment Needs for Curb Ramps



The estimated maintenance cost is similar for the current and desired approaches. However, the capital investment need under the desired approach is approximately 58% more than the current approach. The higher level of investment under the desired approach corresponds to a significant increase in replacement activities. This increase will help MnDOT meet its desired performance target of no more than 6% of the curb ramps in non-complaint condition.

Figure 6-47 shows the performance trends (in terms of percent compliant) for sidewalks over 10 years for each LCP strategy investigated. The desired approach results in almost 95% of the sidewalks in compliant condition. The current approach results in 69% compliant. Under the desired approach, the fraction of the assets in a compliant condition increases rapidly over the first five years and thereafter, the performance levels are sustained. Under MnDOT's current approach, the performance improves slowly over the 10 years. To see how the desired and current approach treatments differ, see Appendix C.

Figure 6-47: Comparison of Current and 10-Year Projected Conditions for Sidewalks



A snapshot of the 10-year performance for sidewalks is shown in Figure 6-48, and Figure 6-49 presents the investment needs associated with the current and desired approaches.

Figure 6-48: Comparison of Current and 10-Year Projected Conditions for Sidewalks

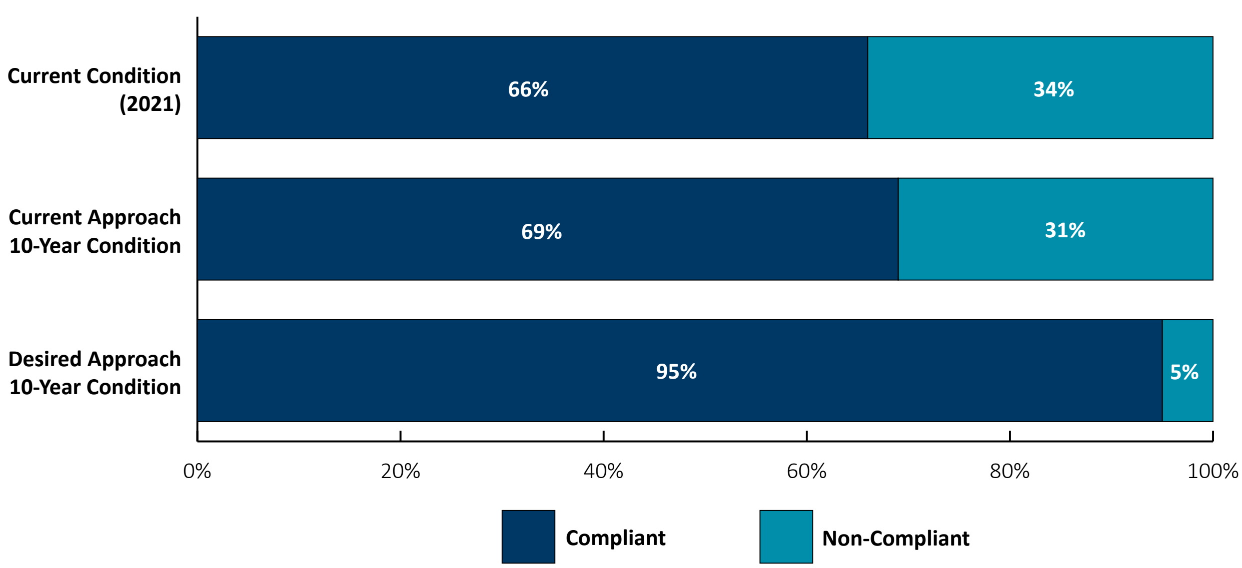
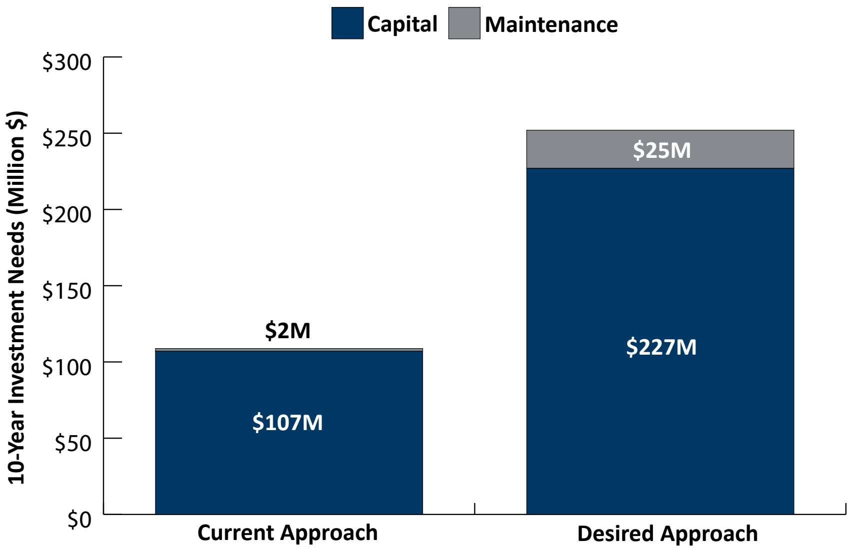


Figure 6-49: 10-Year Investment Needs for Sidewalks



While the current approach slowly improves conditions, it is evident that the budget level for sidewalks is insufficient to make rapid progress towards the desired performance target of no more than 5% of the sidewalk assets in non-compliant condition. To achieve the desired performance level, the capital budget would need to double, and the maintenance budget would need to increase from $1.8 million to $25 million. The increase in maintenance funding would allow sidewalk usability improvements beyond compliance, such as vegetation removal and grinding. Under the desired approach, a significantly higher amount of the increased capital funding is allocated to panel replacements and complete sidewalk reconstruction activities.

TAKEAWAYS

Maintenance and capital investments should focus on non-compliant curb ramps to meet the established performance targets for curb ramps. MnDOT will need to increase the frequency of curb ramp replacements, among other investments. This is also true for sidewalks, but with panel replacements as a critical investment to reduce the area of non-compliant sidewalks.

TRAFFIC SIGNALS

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

Minor rehabilitation activities performed include replacing LED indications and replacing the electronics. Most of the responsibility for inspecting and maintaining these structures falls on MnDOT Electrical Services and district staff. Figure 6-50 summarizes the list of treatment actions considered for signals and the estimated distribution of funding from maintenance and capital budgets.

Figure 6-50: Treatment Actions for Traffic Signals and Estimated Distribution of Funding from Maintenance and Capital Budgets

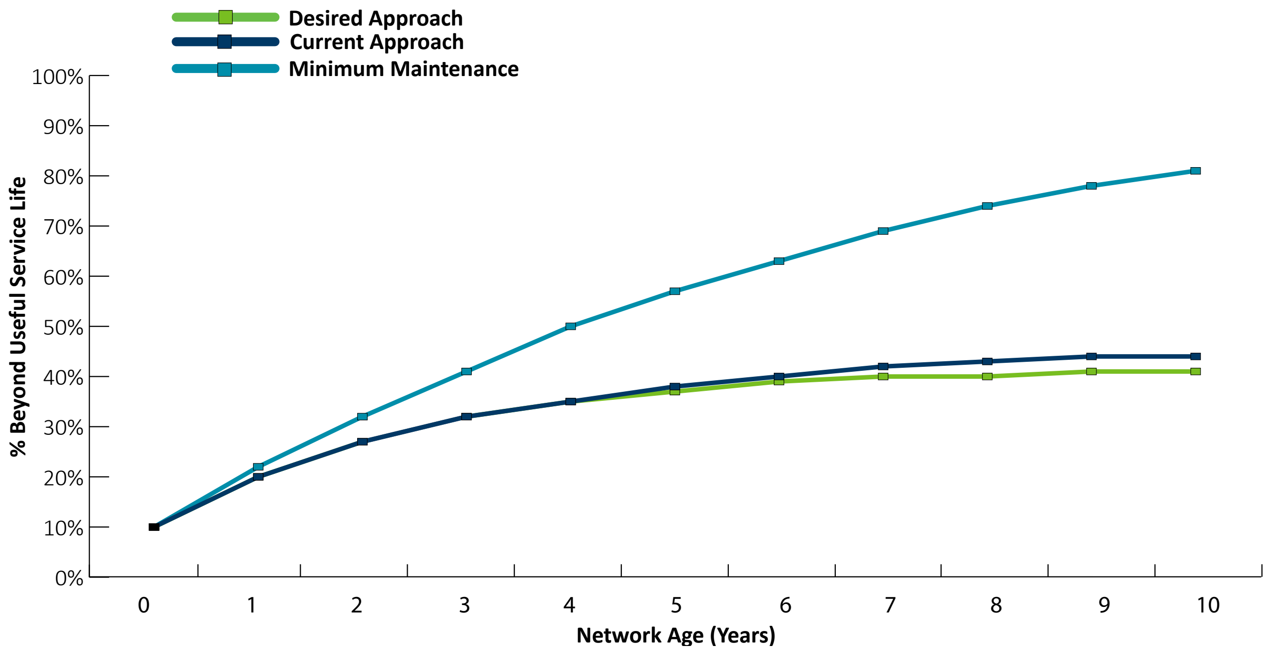
TREATMENT	MAINTENANCE FUNDING	CAPITAL FUNDING
Structural Inspection	50%	50%
Reactive Maintenance	100%	0%
Operations Check	100%	0%
Electrician Preventive Maintenance	100%	0%
Electronic Preventive Maintenance	100%	0%
Replace LED Indications	50%	50%
Replace Electronics	30%	70%
Complete Replacement	10%	90%
PM Treatment	95%	5%

Appendix C provides additional details on the input parameters and analysis assumptions.

ANALYSIS RESULTS

Figure 6-51 shows the performance trends (in terms of percent beyond useful service life) for signals over 10 years for each LCP strategy investigated. The current and desired approaches result in approximately 44% and 41% of the assets in a beyond useful service life condition state, respectively, after 10 years. The minimum maintenance approach results in over 80% of the assets in a beyond useful service life condition. Due to the low level of service from this approach, it was not considered further. To see how the desired and current approach treatments differ, see Appendix C.

Figure 6-51: 10-Year Performance Trends for Traffic Signals



The distribution of the conditions over the 10-year performance period for signals is shown in Figure 6-52. The figure illustrates the benefits associated with the desired maintenance strategy.

Figure 6-52: Comparison of Current and 10-Year Projected Conditions for Traffic Signals

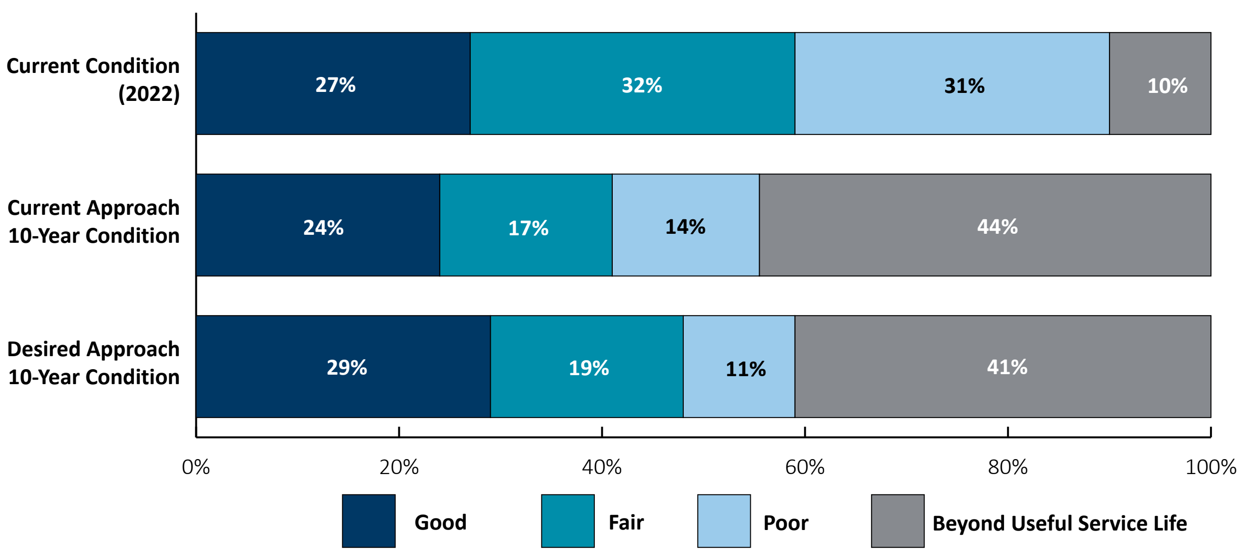
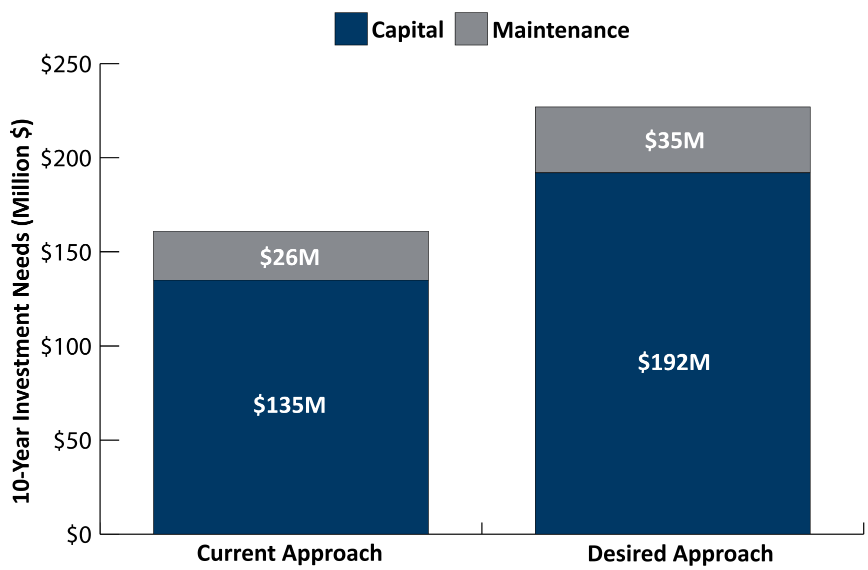


Figure 6-53 presents the investment needs associated with the current and desired approaches. The maintenance investment need under the desired approach is approximately 35% higher than the current approach. The capital investment need under the desired approach is approximately 42% higher than the current approach.

Even with a significant increase in investments under the desired approach, MnDOT will not be able to meet the established performance target of no more than 2% of the assets in the beyond useful service life condition state. This is because it only takes six years to transition from a poor to a beyond useful service life condition state and once the asset transitions to the worst possible condition state, the only activity that will restore the condition of the asset is complete replacement. Replacements require a significant investment. While the desired life-cycle management approach cannot meet the established performance target in the 10-year timeframe, it reflects a marginal improvement in the assets in good condition. Over the long-term (>10 years), the desired approach is expected to maintain steady-state conditions, and any additional funding can help MnDOT make significant progress towards the established performance target.

Maintenance spending increases in the desired approach because MnDOT staff believe that operations checks, electrician preventive maintenance and electronic preventive maintenance could extend how long it takes for a signal to be beyond useful service life. Maintenance benefits are not accounted for because the performance measure for signals is age-based—making a signal that is 30 years or older beyond useful service life by default.

Figure 6-53: 10-Year Investment Needs for Traffic Signals



TAKEAWAYS

- Over 70% of the signals are in a fair to beyond useful service life condition state, which indicates the need for more capital replacements. Replacements are needed since the asset conditions and performance targets are based on asset age.
- Preventive maintenance actions, operation checks and LED replacements were assumed not to extend the expected service life of signal assets in the analysis. MnDOT is working toward establishing an asset condition score based on inspections (and not asset age) and this is expected to improve the life-cycle management approach for signals in the future.

LIGHTING

MnDOT does not have a consistent inspection schedule for lighting structures, although electrical inspections are conducted every five years. Minor rehabilitation activities performed include LED and electronics replacements. Most of the responsibility for inspecting and maintaining these structures falls on MnDOT Electrical Services and district staff. Figure 6-54 summarizes the list of treatment actions considered for lighting along with the estimated distribution of funding from maintenance and capital budgets.

Figure 6-54: Treatment Actions for Lighting and Estimated Distribution of Funding from Maintenance and Capital Budgets

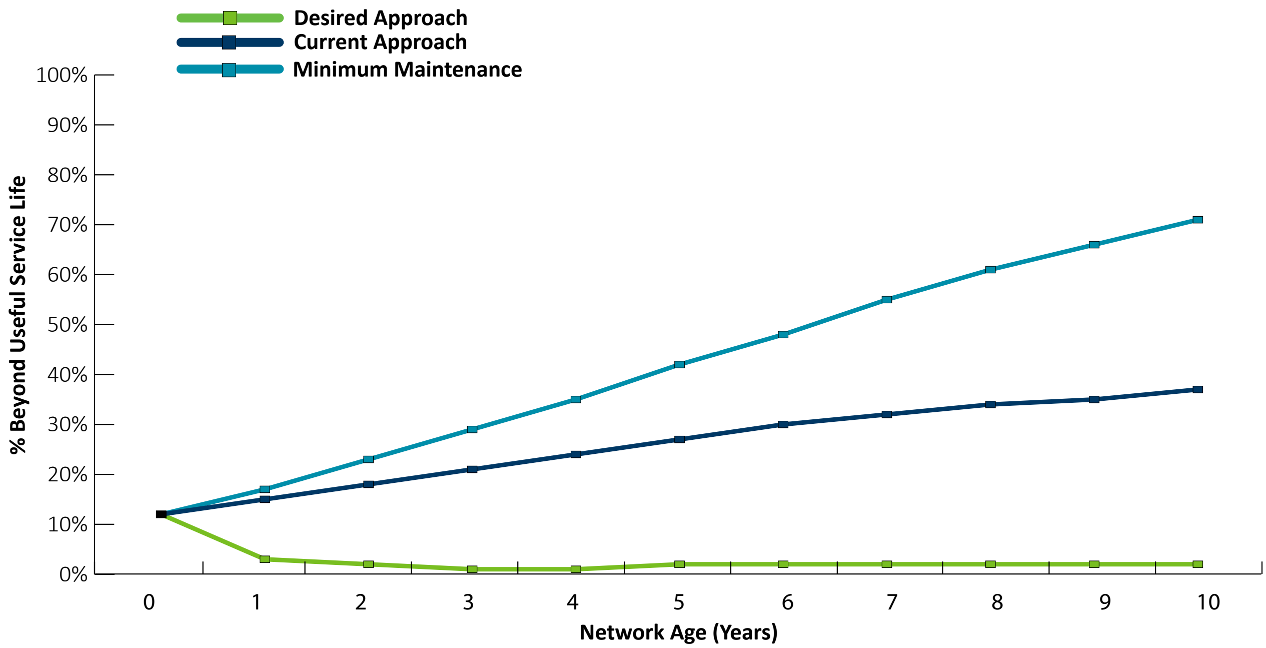
TREATMENT	MAINTENANCE FUNDING	CAPITAL FUNDING
Knockdowns and Replacements	100%	0%
Reactive Maintenance	100%	0%
Electrical Inspection	100%	0%
Replace Luminaires	10%	90%
Structural Inspection	30%	70%
PM Treatment	100%	0%
Complete Replacement	0%	100%

Appendix C provides additional details on the input parameters and analysis assumptions.

ANALYSIS RESULTS

Figure 6-55 shows the performance trends (in terms of percent beyond useful service life) for lighting over 10 years for each LCP strategy investigated. The desired approach results in less than 2% of the assets in a beyond useful service life condition state and the current approach results in almost 37% of the assets being in beyond useful service life condition state after 10 years. In comparison, the minimum maintenance approach results in over 70% of the assets in a beyond useful service life condition state. Due to the low level of service from this approach, it was not considered further. To see how the desired and current approach treatments differ, see Appendix C.

Figure 6-55: 10-Year Performance Trends for Lighting



The distribution of conditions over the 10-year performance period for lighting is shown in Figure 6-56. The figure illustrates the benefits associated with the desired strategy.

Figure 6-56: Comparison of Current and 10-Year Projected Conditions for Lighting

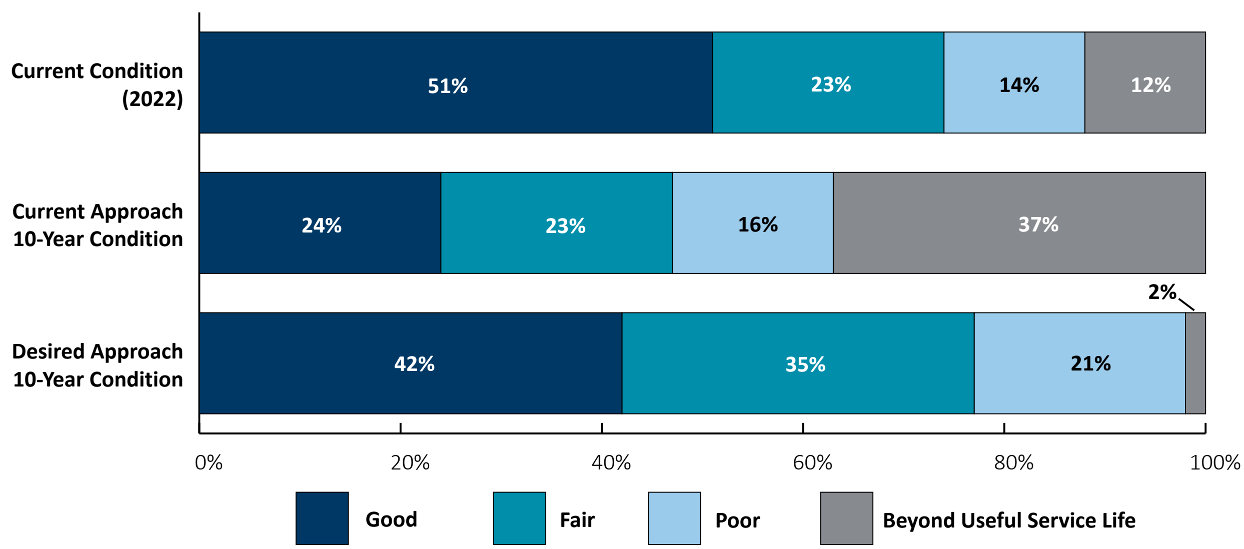
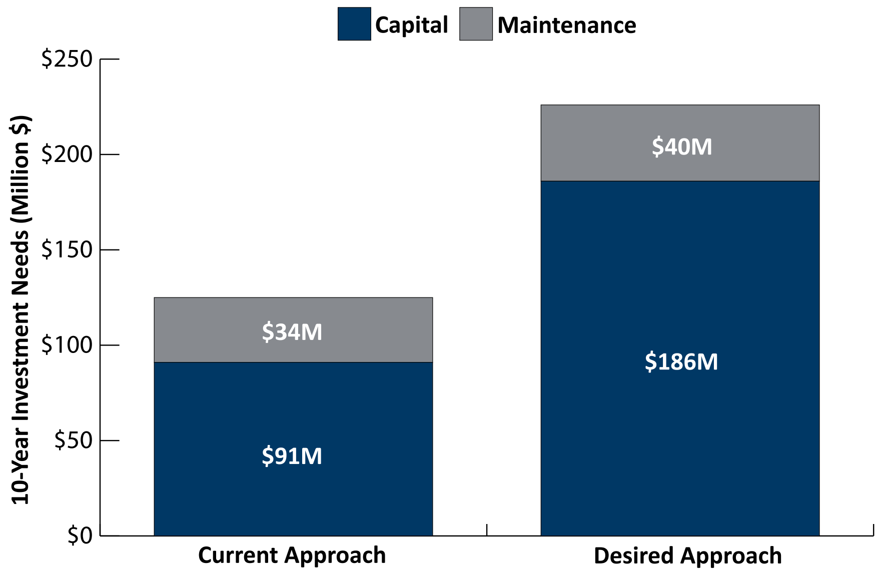


Figure 6-57 presents the investment needs associated with the current and desired approaches. The maintenance investment needed under the desired approach is approximately 18% more than the current approach. This is tied to an increase in electrical and structural inspections. The capital investment need under the desired approach is more than double the investment need under the current approach. The capital increase is due to replacements for lighting beyond useful service life. A funding increase will help MnDOT meet its desired performance target of no more than 2% of lighting in the beyond useful service life condition state.

Maintenance spending increases in the desired approach because MnDOT staff believe that electrical and structural inspections could extend how long it takes for lighting to be beyond useful service life. Maintenance benefits are not accounted for because the performance measure for lighting is age-based—making lighting that is 30 years or older beyond useful service life by default.

Figure 6-57: 10-Year Investment Needs for Lighting



TAKEAWAYS

- As with signal assets, the age-based condition and performance target limit preventive maintenance's impact to extend asset service life.
- A significant increase in signal replacements would be needed to meet the established performance target.
- MnDOT is working toward establishing an asset condition score based on inspections (and not asset age). This is expected to improve the life-cycle management approach for lighting assets in the future.

HIGH-MAST LIGHT TOWERS

High-mast light towers are inspected on a five-year cycle under MnDOT's inspection program, which is similar to the element level inspection program for overhead sign structures. The protocols for inspection and management of high-mast light tower structures have been part of a regularly defined program for over two decades. Over the last five years, MnDOT has invested significant resources in improving the life-cycle management of these assets.

Typical maintenance actions performed on high-mast light towers include tightening and leveling of nuts, removing debris, and replacing components that are not functioning adequately. Most of the responsibility for inspecting and maintaining these structures falls on district staff, and MnDOT has developed cost-recording protocols to improve the cost data for these assets. Figure 6-58 summarizes the list of treatment actions considered for high-mast light towers along with the estimated distribution of funding from maintenance and capital budgets.

Figure 6-58: Treatment Actions for High-Mast Light Towers and Estimated Distribution of Funding from Maintenance and Capital Budgets

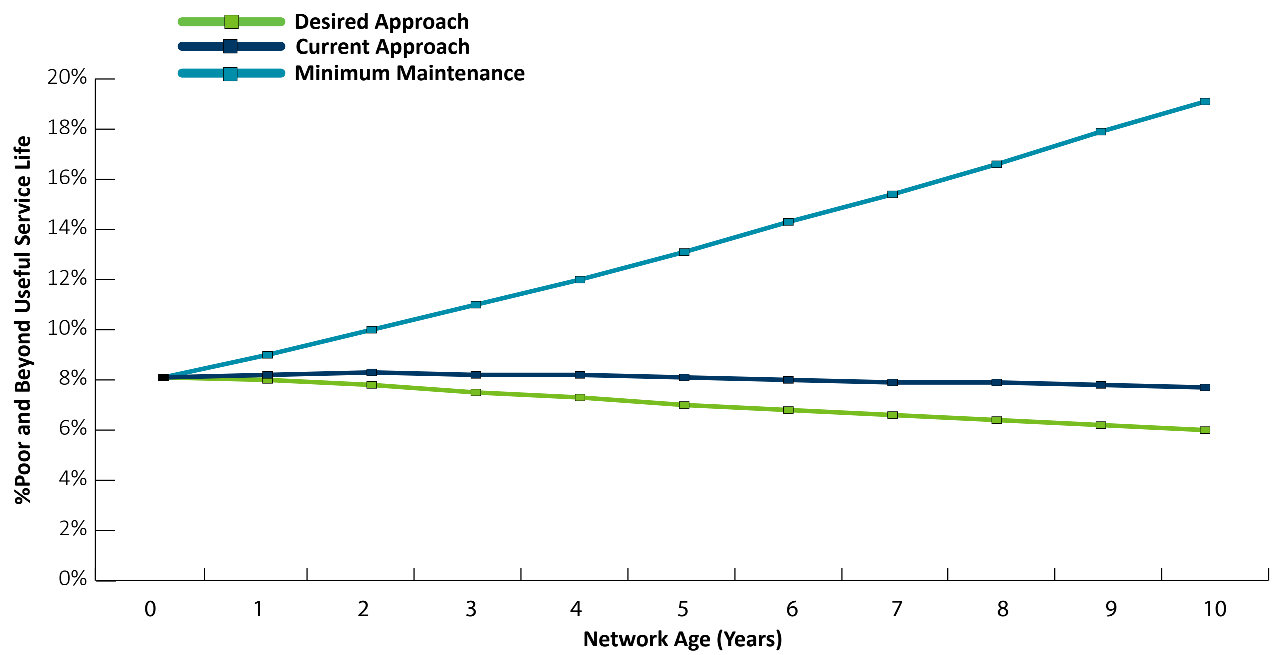
TREATMENT	MAINTENANCE FUNDING	CAPITAL FUNDING
Structural Inspection	100%	0%
Tighten Nuts and Winch replacement	100%	0%
Out-of-Cycle Inspection I (excluding Removal and Replacement)	100%	0%
Out-of-Cycle Inspection II (including Removal and Replacement)	0%	100%
Replace LED Luminaires	0%	100%
Exercise Lowering Mechanism	0%	100%
Removal and Replacement	0%	100%

Appendix C provides additional details on the input parameters and analysis assumptions.

ANALYSIS RESULTS

Figure 6-59 shows the performance trends (in terms of percent poor and beyond useful service life) for high-mast light towers over 10 years. The desired approach results in approximately 6 % of the assets in poor condition and the current approach results in almost 8% in poor condition after 10 years. In comparison, the minimum maintenance approach will result in almost 20% in poor condition. Due to the low level of service from this approach, it was not considered further. To see how the desired and current approach treatments differ, see Appendix C.

Figure 6-59: 10-Year Performance Trends for High-Mast Light Towers



The distribution of conditions over the 10-year performance period for high-mast light towers is shown in Figure 6-60. The figure reflects slightly better conditions under the desired approach than with the current approach.

Figure 6-60: Comparison of Current and 10-Year Projected Conditions for High-Mast Light Towers

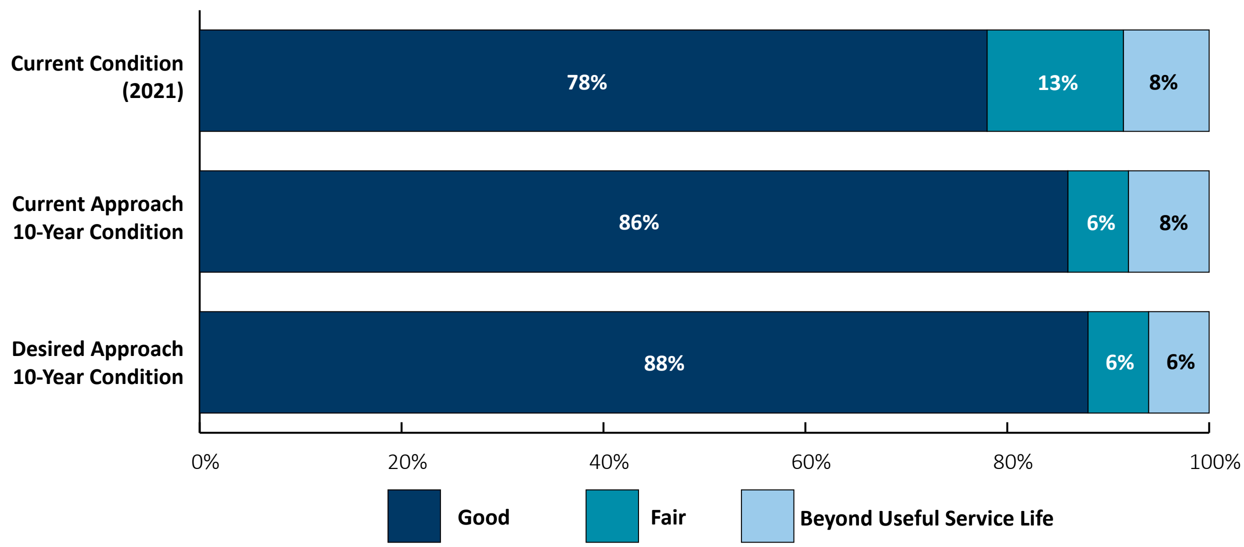
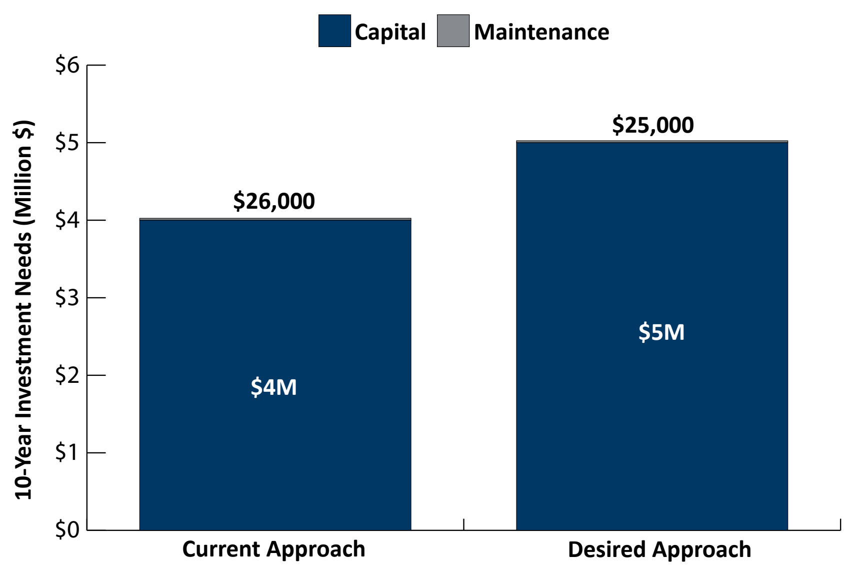


Figure 6-61 presents the investment needs associated with the current and desired approaches. The maintenance need for the desired approach is similar to the current approach, however, the capital investment need is approximately 20% higher. Additional investments under the desired approach including an increase in the frequency of removal and replacements will help MnDOT meet the desired performance target of no more than 6% of the assets in poor or worse condition.

Figure 6-61: 10-Year Investment Needs for High-Mast Light Towers



TAKEAWAYS

Most of the high-mast light towers are in good condition and follow a condition-based inspection approach. Investing in strategic preventive maintenance will maintain the assets in a good state of repair over their design life. In 10 years, the established performance target of no more than 6% of the assets in poor condition will be met.

FINANCIAL PLANNING

Capital investment decisions and future revenue projections are part of the 20-Year Minnesota State Highway Investment Plan. 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, risks to the highway system and public input. MnSHIP was last updated in 2018. A new plan will be completed in 2023 and will include an updated capital investment direction.

Over the next 10 years, MnDOT will balance investments in preserving and maintaining the existing highway system with other priority investment objectives as established in MnSHIP.

Financial trends indicate that revenues have slowed compared to previous decades. As a result, MnDOT must look for investment opportunities that provide the best return on investment in the long term. Timely investments in both capital and maintenance treatments help extend the service life of assets while reducing life cycle costs (discussed in **Chapter 6: Life Cycle Planning**). 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 the lowest life cycle costs (discussed in **Chapter 5: Risk Management**).

This chapter summarizes funding sources, trends, current revenues and highlights investment levels and strategies for the asset categories. It also includes estimates of the investment levels necessary to achieve asset condition performance targets by 2032, the end of the TAMP's planning period.

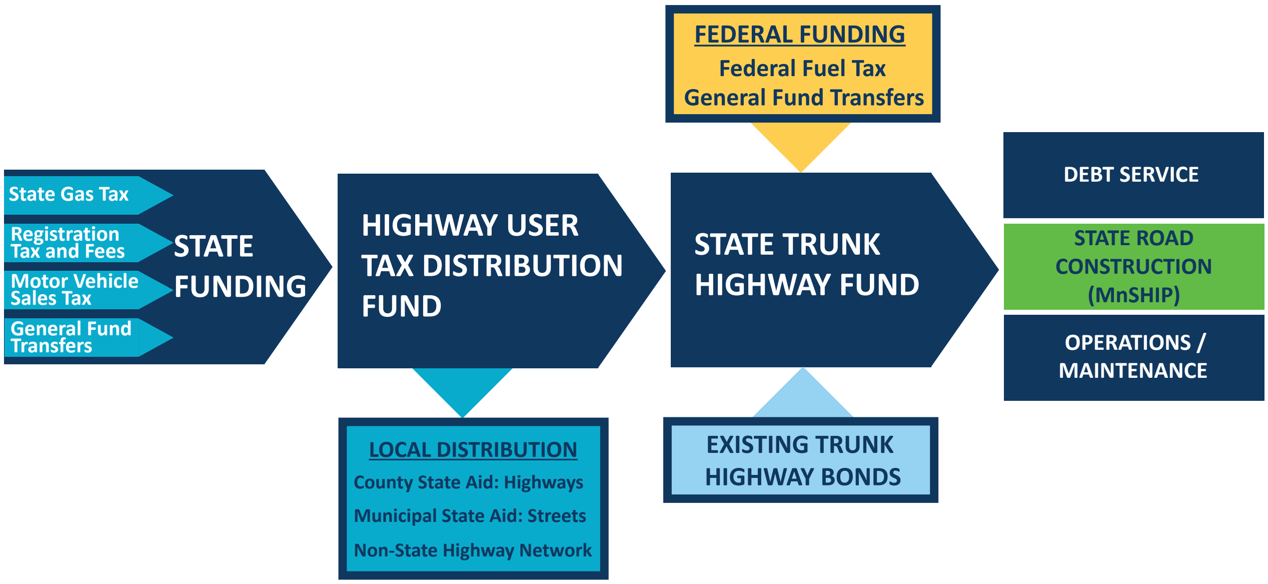
REVENUE SOURCES

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

- Federal aid (mainly gas tax and general funds)
- State gas tax (motor fuel excise tax)
- State tab fees (motor vehicle registration tax)
- State motor vehicle sales tax
- Transportation-related taxes transferred from the state General Fund (these include sales tax on auto parts, motor vehicle rental and sales tax, and motor vehicle lease sales tax)

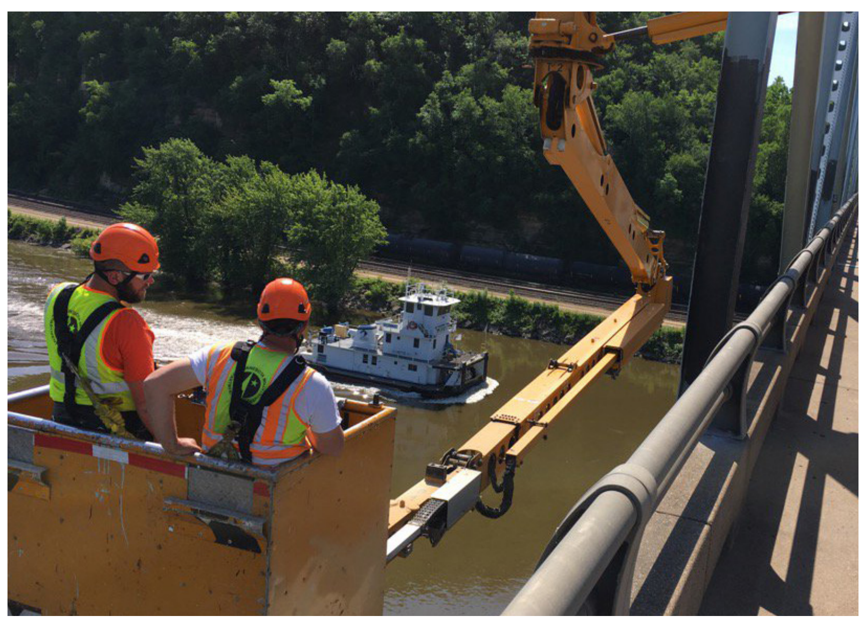
Federal aid revenues go directly to the State Trunk Highway Fund (see Figure 7-1), which funds capital improvements on the state highway system. Revenues from the main state sources and various smaller revenues are pooled into the Highway User Tax Distribution Fund and divided between state highways, county roads and city streets based on a constitutional formula.

Figure 7-1: Revenue Sources and Uses for the Minnesota State Highway Network



Approximately 5% of these funds are set aside for the non-State Highway Network (including the Flexible Highway Account, Township Roads Account and Township Bridges Account). The remaining 95% is split among the State Trunk Highway Fund, County State Aid Highways and Municipal State Aid Streets. The 62% portion allocated from the HUTDF to the State Trunk Highway Fund must first go toward any existing debt repayment and then is divided among operations and maintenance activities, and capital improvements on state highways.

In addition to the five primary funding sources, Minnesota also sells transportation bonds to support highway improvements. However, unlike the other revenue sources, bonds are 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 occasionally receives short-term state highway funds from general fund transfers to the HUTDF. Recently, this occurred during the 2017 Minnesota legislative session. However, it is difficult to project the frequency and size of these transfers into the future.

REVENUE AND INFLATION

CAPITAL

Over the next 10 years, MnDOT estimates that $10.1 billion in revenue will be available for capital investment on the state highway system, which translates to approximately $1 billion per year. This estimate assumes that no new significant sources of revenue will be introduced and that the majority of MnDOT's future revenues will originate from the five main revenue sources shown at the top of Figure 7-1. This revenue estimate does not include additional federal funding from the Infrastructure Investment and Jobs Act. At the time of publication of the TAMP, investment decisions on the new federal funding had not been made.

MnDOT anticipates that the actual amount of funding it receives from the State Trunk Highway Fund will increase by approximately 2% per year over the next 10 years. However, construction costs are growing more quickly than revenues. As a result, 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 nearly 5%, which is a slight tapering off from the past decade, but exceeds the annual revenue growth rate of approximately 2%. Figure 7-2 illustrates the impact of inflation on annual buying power (blue) versus nominal funding (green) in future years of construction. The net effect is that inflation will erode buying power by 40% by 2032, given the assumptions stated above.

Figure 7-2: Anticipated Construction Funding by Year Including Adjustments for Inflation

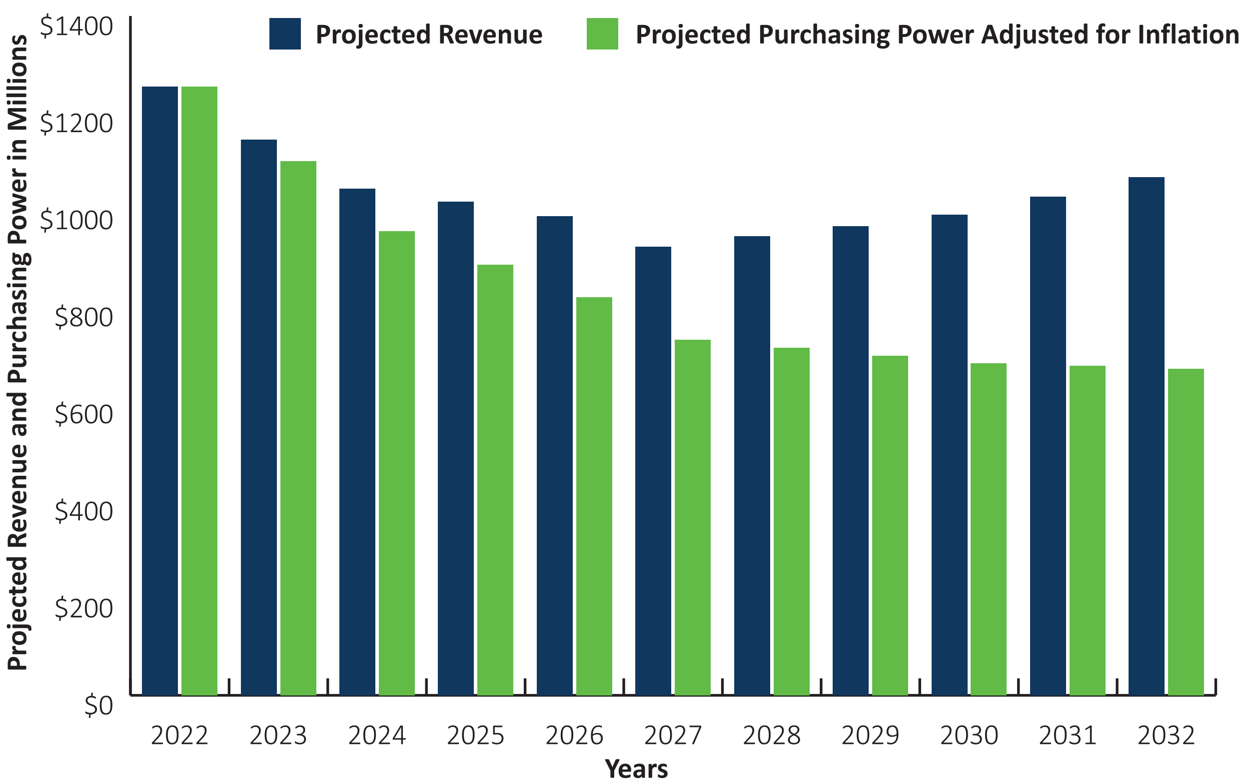


Figure 7-3 illustrates annual construction revenue over the next 10 fiscal years. These construction revenue estimates are the basis for the asset investment strategies in the TAMP.

Figure 7-3: Anticipated Construction Revenue

FISCAL YEAR	CONSTRUCTION REVENUE (IN MILLIONS)
2023	$1,145
2024	$1,044
2025	$1,017
2026	$988
2027	$924
2028	$946
2029	$966
2030	$990
2031	$1,028
2032	$1,068

OPERATIONS AND MAINTENANCE

MnDOT has a maintenance and operations workforce of approximately 2,300 employees spread across eight districts. The department spends approximately $370 million annually operating and maintaining Minnesota's state highway system. Clearing snow and ice from the trunk highway system is a priority service, and staffing levels are set with snow and ice operations in mind.

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

- Pavement preventive and reactive maintenance
- Bridge preventive and reactive maintenance
- Infrastructure inspections
- Culvert and drainage system preventive and reactive maintenance
- Sign maintenance and replacements
- Traffic barrier reactive maintenance
- Highway striping and message placement
- Signal and lighting maintenance
- Vegetation control
- Other activities, such as incident response, and debris and graffiti removal

During the 2019 TAMP process, MnDOT concluded that it needed better integration between its capital and maintenance investment decisions.

In the intervening years, a substantial effort was made to establish performance measures for maintenance activities, which are part of the life cycle management for many asset classes. Numerous operational performance measures have been developed but are not considered to directly support asset life cycle management and, therefore, are not considered in this TAMP.

MnDOT's Transportation Asset Management System has performed well as a tool to capture and model maintenance costs in direct relation to asset condition for pavements, culverts, overhead sign structures and high-mast tower lighting. In 2022, maintenance performance measures were coded directly into the software. This allows for an automated generation of work demand relative to asset needs and will be very beneficial to the department's ability to forecast and execute needed work, especially high-value preventive maintenance.

FUNDING PROGRAM OVERVIEW

MnDOT invests in state highway projects through two primary programs: the Statewide Performance Program and the District Risk Management Program. The purpose of establishing these two programs is to ensure the agency efficiently and effectively works toward common statewide goals - in particular, meeting identified outcomes of the MnSHIP investment direction while maintaining some flexibility to address unique risks and circumstances at the district level.

STATEWIDE PERFORMANCE PROGRAM

MnDOT created the SPP in 2013 to respond to an increased federal emphasis on National Highway System performance, which requires MnDOT to make progress toward national performance goal areas. The SPP manages investment and project selection on the NHS to meet statewide outcomes listed in the MnSHIP investment direction. 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. Selected SPP projects are added annually in year 10 of the 10-Year Capital Investment Highway Plan.

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 State Transportation Improvement Plan, each MnDOT district is responsible for designing and delivering the selected projects.

DISTRICT RISK MANAGEMENT PROGRAM

The DRMP focuses funding for performance-based needs on non-NHS highways and non-performance-based needs on all state highways. Most of the program supports non-NHS pavement and bridge rehabilitation or replacement projects. The DRMP project selection process is structured to give districts the flexibility to address their most significant regional and local risks.

MnDOT distributes funding to the districts for this program based on a Resource Distribution Formula that accounts for various system factors (Figure 7-4). The funds each district receives for programming its DRMP projects are determined through this target formula. The Resource Distribution Formula considers five factors at the district level: projected condition for non-NHS pavement, projected condition for non-NHS bridges, the portion of total trunk highway lane miles, total VMT and heavy commercial VMT. The amount allocated to each district depends on these factors, according to the breakdown below.

MnDOT revises the distribution annually based on the most recent data and applies the distribution to years 5-10 in the CHIP. DRMP funding remains unaffected in the first four years of the current CHIP. The process is designed to give districts fixed funding in years 1-4 to program and finalize the scope of projects. This process ensures a more accurate reflection of the remaining needs in each district as projects are 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.

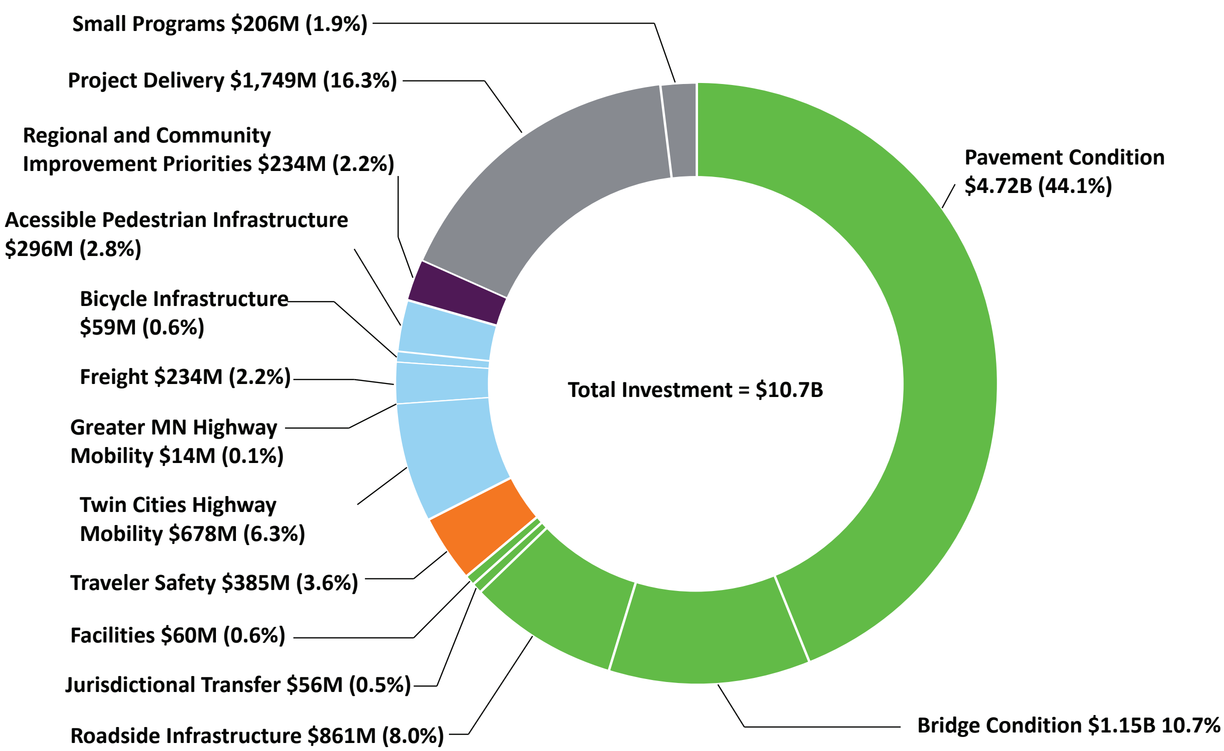
Figure 7-4: Resource Distribution Formula Factors

DISTRIBUTION FACTORS	PERCENT OF FORMULA	DATA SOURCES
Non-NHS Pavement Condition	20%	Pavement model run using current condition data to identify the annual funding needed for each district to reach 60% good and 10% poor
Non-NHS Bridge Condition	20%	BRIM run based on remaining service life using current condition data to identify the annual funding needed to reach 50% good and 8% poor
Trunk Highway Lane Miles	30%	Most recent lane mile inventory
Vehicle Miles Traveled	24%	Most recent vehicle miles traveled data
Heavy Commercial VMT	6%	Most recent heavy commercial vehicle miles traveled data (Only on state highways)

INVESTMENT PRIORITIES AND DIRECTION

MnDOT's primary focus for the next 20 years is on preserving and maintaining the existing state highway system. Most available resources are directed to asset management categories, primarily Pavement Condition, Bridge Condition, and Roadside Infrastructure Condition. The Roadside Infrastructure Condition category includes highway culverts, deep stormwater tunnels, overhead sign structures, high-mast light tower structures, Intelligent Transportation Systems, signals, lighting, noise walls as well as several other asset categories not included in this TAMP. Facilities includes investment for rest areas, weigh stations and scales. Figure 7-5 shows the planned investments during the time frame covered by the TAMP (2023-2032).

Figure 7-5: 2023-2032 Planned Capital Investments



MnDOT manages this 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 non-Interstate 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 only $10.31 billion for investing on pavements and $2.38 billion on bridges. Figure 7-6 shows the need and the average yearly investment. 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 7-6: Average Pavement 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

ASSET INVESTMENT STRATEGIES

Pavement and bridge conditions in Minnesota are relatively well-understood and documented due to long-standing condition surveys and databases. The districts use information from the pavement management system 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 3: Asset Inventory, Condition and Valuation** of this plan.

PAVEMENTS

MnDOT's Highway Pavement Management Application (discussed in **Chapter 2: Asset Management Planning and Programming Framework**) determines the capital investment needs and outcomes developed for MnSHIP. MnDOT conducts model runs to determine future pavement performance based on the planned investment direction. Each year, these model runs are updated with the planned investments in the 10-year CHIP.

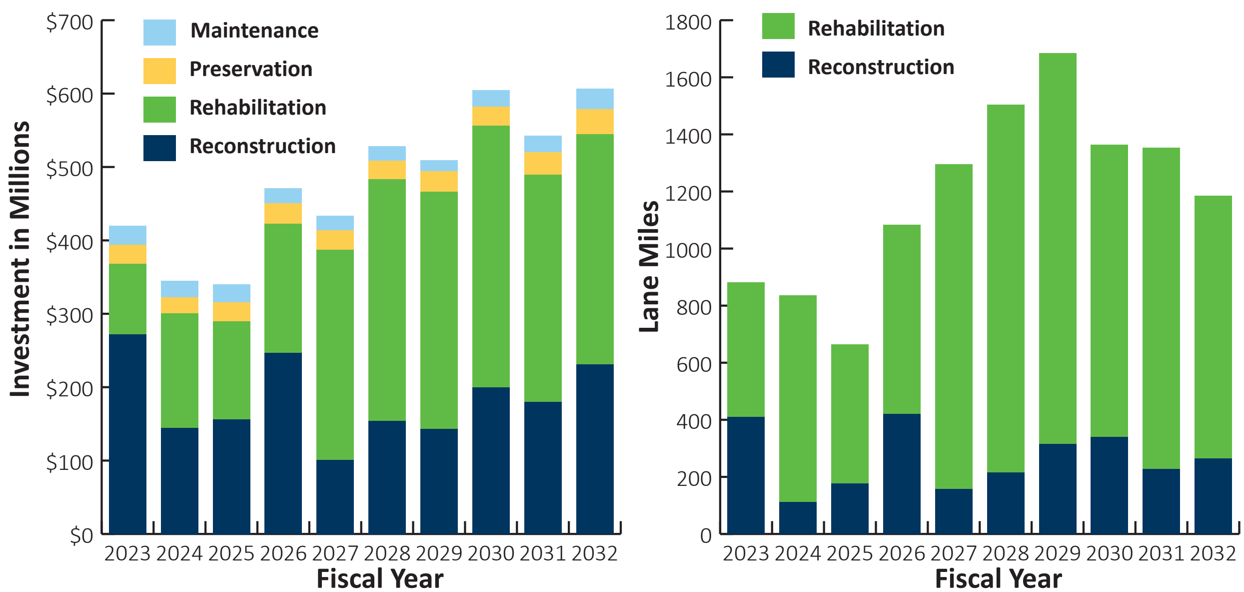
In addition to the larger pavement improvements identified by the pavement model, MnDOT also invests in preventive maintenance of its pavements. MnDOT districts either program projects in their STIP or use a capital setaside to fund preventive maintenance activities to meet newly established preventive maintenance performance targets. MnDOT's pavement model assumes that preventive maintenance activities are being addressed. The model considers the amount of planned district investment towards preventive maintenance. Preventive maintenance is supplemented by MnDOT maintenance, which is funded through the operations budget. As noted above, MnDOT plans for and tracks this work within TAMS.

Between 2023 and 2032, MnDOT identified capital pavement expenditures of $1 billion on the Interstate system, $2.4 billion on the non-Interstate NHS and $1.4 billion on the non-NHS, for a total of $4.8 billion (as shown in **Chapter 4: Asset Management Performance Measures, Targets and Performance Gaps**). Investments in pavement maintenance will total approximately $220 million and include yearly setasides for seasonal road repairs. Breaking the investment out by type of fix, MnDOT anticipates investing $1.8 billion on reconstruction projects, $2.5 billion on rehabilitation projects and $273 million on preservation projects over the next 10 years.

Figure 7-7 shows yearly investment and lane miles addressed by work type. Preservation work includes crack filling, joint sealing and chip seals that help to slow deterioration. Rehabilitation work includes mill and overlays of various thicknesses, concrete pavement repairs, concrete panel replacement or cold in-place recycling. Reconstruction work includes replacement of the entire roadway, reclaims or unbonded overlays.

MnDOT is unable to estimate the amount of lane miles to be completed with preservation or maintenance investments. Most of the investments are held in yearly setasides for projects to be identified in the future. MnDOT does not generally identify preservation or maintenance projects more than a year in advance.

Figure 7-7: Yearly Pavement Investment and Lane Miles by Work Type



Figures 7-8 and 7-9 show pavement investment amounts and lane-miles addressed by work type and system through 2032.

Figure 7-8: Yearly Pavement Investment by FHWA Work Type and by System

Note: Preservation and maintenance future planned investments are held as districtwide yearly setasides and locations are not identified in advance.

WORK TYPE	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Reconstruction	$272 M	$145 M	$156 M	$246 M	$101 M	$154 M	$143 M	$200 M	$179 M	$231 M
Interstate	$43 M	$86 M	$92 M	$24 M	$7 M	$8 M	$42 M	$51 M	$66 M	$61 M
Remaining NHS	$170 M	$35 M	$56 M	$158 M	$68 M	$123 M	$41 M	$117 M	$86 M	$124 M
Non-NHS	$59 M	$24 M	$8 M	$65 M	$26 M	$23 M	$60 M	$32 M	$27 M	$47 M
Rehabilitation	$97 M	$156 M	$133 M	$177 M	$286 M	$329 M	$323 M	$356 M	$310 M	$314 M
Interstate	$22 M	$6 M	$4 M	$30 M	$37 M	$36 M	$104 M	$93 M	$70 M	$58 M
Remaining NHS	$38 M	$100 M	$82 M	$87 M	$185 M	$174 M	$128 M	$183 M	$128 M	$160 M
Non-NHS	$37 M	$50 M	$48 M	$60 M	$64 M	$119 M	$91 M	$81 M	$112 M	$96 M
Preservation	$25 M	$22 M	$26 M	$27 M	$27 M	$26 M	$29 M	$26 M	$31 M	$34 M
Maintenance	$26 M	$23 M	$25 M	$21 M	$20 M	$20 M	$15 M	$22 M	$22 M	$28 M
New Construction	$0 M	$0 M	$0 M	$0 M	$0 M	$0 M	$0 M	$0 M	$0 M	$0 M
Total	$420 M	$345 M	$340 M	$471 M	$434 M	$528 M	$509 M	$604 M	$542 M	$607 M

Figure 7-9: Yearly Pavement Lane Miles by FHWA Work Type and System

WORK TYPE	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Reconstruction	409	111	176	420	157	215	314	339	228	263
Interstate	86	13	63	80	-	29	86	49	10	46
Remaining NHS	176	72	101	183	129	101	112	237	167	142
Non-NHS	146	26	12	157	29	85	116	53	50	75
Rehabilitation	473	725	488	664	1,138	1,289	1,371	1,025	1,126	922
Interstate	81	42	-	129	91	147	393	77	169	125
Remaining NHS	181	377	242	264	665	590	539	532	487	431
Non-NHS	211	306	246	271	382	552	439	416	470	366
New Construction	0	0	0	0	0	0	0	0	0	0
Total	882	836	664	1,084	1,296	1,504	1,685	1,364	1,353	1,185

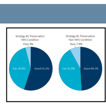
BRIDGE

Investment needs and outcomes for bridges were established using MnDOT's bridge management system for bridge inventory and condition data and MnDOT's BRIM system for prioritization and cost estimates (discussed in **Chapter 2: Asset Management Planning and Programming Framework**).

The life cycle of a bridge offers multiple opportunities for maintenance and life extension. Deterioration from age, traffic and chemicals constantly degrade bridge condition. Preventive maintenance work tends to slow the rate of deterioration but does not prevent damage from eventually taking place. If timely repairs are made, conditions can be maintained or improved, thus extending the service life. Eventually, age and deferred maintenance cause a bridge to slip into a poor condition where only expensive rehabilitation and replacement can restore the needed level of performance.

Preservation actions are funded from either the capital budget or the operations budget, depending on the magnitude of the work. It is anticipated that approximately $20 million (10-year projected average, adjusted for inflation) is spent annually on preventive and reactive bridge maintenance from MnDOT's operations budget. Inspections constitute another $3 million to $4 million from the operations budget. MnDOT considers preventive maintenance as the next highest priority behind inspections and critical maintenance. The agency has had a strong preservation culture for many years by accomplishing key activities, such as flushing, crack sealing, joint sealing, rail sealing, joint maintenance and other minor repairs on a regular schedule for most of its bridges. Despite these commitments, preservation is underfunded for bridges and would benefit from improved planning tools to correctly size the budget, select the best candidates for preservation and produce a more balanced investment plan. The typical strategy used by MnDOT to develop investment levels for bridges is summarized in Figure 7-10. MnDOT is continually improving data collection, analysis, reporting and performance measure tools to promote improved planning and investment.

Figure 7-10: MnDOT Typical Investment Strategy for Bridges

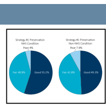


Determine initial fraction of statewide bridge decks in good, fair and poor conditions

Plan and prioritize investments with a risk-based approach.The primary goal is to meet bridge performance targets (through major preservation and rehabilitation) while making appropriate investment in the right type of treatments for the right structure at the right time

Schedule preventive maintenance, minor repairs and major preservation to slow deterioration rates and maximize service life

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



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

Another investment strategy that MnDOT employs is the Bridge Priority Preservation List (see Figure 7-11). The list shows trunk highway bridges that are an elevated priority due to structure type, cost, size and overall importance. There are three central reasons for the list:

- Maintain these high-priority bridges in good and satisfactory condition for as long as possible.
- Postpone or prevent redecks and replacements for these bridges.
- Reduce overall life cycle costs for bridges.

Figure 7-11: Bridge Priority Preservation List (as of 2020)

MNDOT DISTRICT	BRIDGE NAME	BRIDGE NUMBER	FACILITY	INTERSECTION
1	Blatnik (replacement)	TBD	I 535	St Louis River, Rail Road, Street
1	Bong (**WI lead**)	69100	US 2	St Louis River, TH 35, Rail Road
6	Dresbach	85801	I 90 WB	Mississippi River
6	Dresbach	85802	I 90 EB	Mississippi River
6	Wabasha	79000	TH 60	Mississippi River, Street
6	Winona	5900	TH 43	Mississippi River, Rail Road, Streets
6	Winona	85851	TH 43	Streets, Mississippi River, Rail Road
6	Red Wing	25033	US 63	Mississippi River, Canadian Pacific Railroad
Metro	35W	27409	I 35W SB	Mississippi River, W River Parkway, Road, Rail Road
Metro	35W	27410	I 35W NB	Mississippi River, W River Parkway, Road, Rail Road
Metro	Wakota	82855	I 494 EB	Mississippi River, Union Pacific Railroad
Metro	Wakota	82856	I 494 WB	Mississippi River, Union Pacific Railroad
Metro	St. Croix Crossing	82045	TH 36	St Croix River, TH 95, Union Pacific Railroad
Metro	SCC Ramp	82047	TH 36 WB Ex Ramp	Union Pacific Railroad
Metro	SCC Ramp	82048	TH 36 EB On Ramp	Union Pacific Railroad
Metro	3rd Ave	2440	TH 65 (3rd Ave S)	Mississippi River, City Street
Metro	Smith Ave High Bridge	62090	TH 149	Streets, Mississippi River, Rail Road
Metro	Hastings	19004	US 61	Mississippi River, 2nd Street, N Loop Road
Metro	Cedar	9600N	TH 77 NB	Minnesota River, Black Dog Road
Metro	Cedar	9600S	TH 77 SB	Minnesota River, Black Dog Road
Metro	Mendota Bridge	4190	TH 55	Minnesota River, Rail Road, Street
Metro	35E	62912	I 35E	Mississippi River, Union Pacific Railroad
Metro	Lafayette	62017	US 52 SB	Mississippi River, Rail Road, Streets
Metro	Lafayette	62018	US 52 NB	Mississippi River, Rail Road, Streets
Metro	Black Dog	27W38	I 35W	Black Dog Road, Minnesota River
Metro	Black Dog	27W39	I 35W	Black Dog Road, Minnesota River

For years 2023-2032, MnDOT plans capital and maintenance bridge expenditures of $843 million on NHS bridges and $496 million on non-NHS bridges, totaling $1.3 billion (as shown in **Chapter 4: Asset Management Performance Measures, Targets and Performance Gaps**). Broken out by type of project, MnDOT is projected to invest $200 million in maintenance projects, $380 million in preservation projects, $260 million in rehabilitation projects and $440 million in reconstruction projects. Figure 7-12 shows yearly investment and square footage of deck area by work type. Preservation work includes activities such as bridge painting, deck overlays, joint replacements, substructure repairs and railing or median replacements. Rehabilitation work includes activities such as deck replacement, superstructure replacement or major widening. Reconstruction work includes replacement of bridges or bridge culverts.

The percent of poor bridge deck area on the NHS and non-NHS has increased since 2015. Performance on the NHS is expected to decline significantly over the next 10 years and will not meet the state performance target. The condition of bridges on non-NHS routes is also expected to decline and miss the state performance target by 2032. As noted previously, MnDOT's bridge condition targets state that no more than 5% of NHS bridge deck area and 8% of non-NHS bridge deck area should be in poor condition.

Figure 7-12: Yearly Investment and Square Footage of Deck Area by Work Type

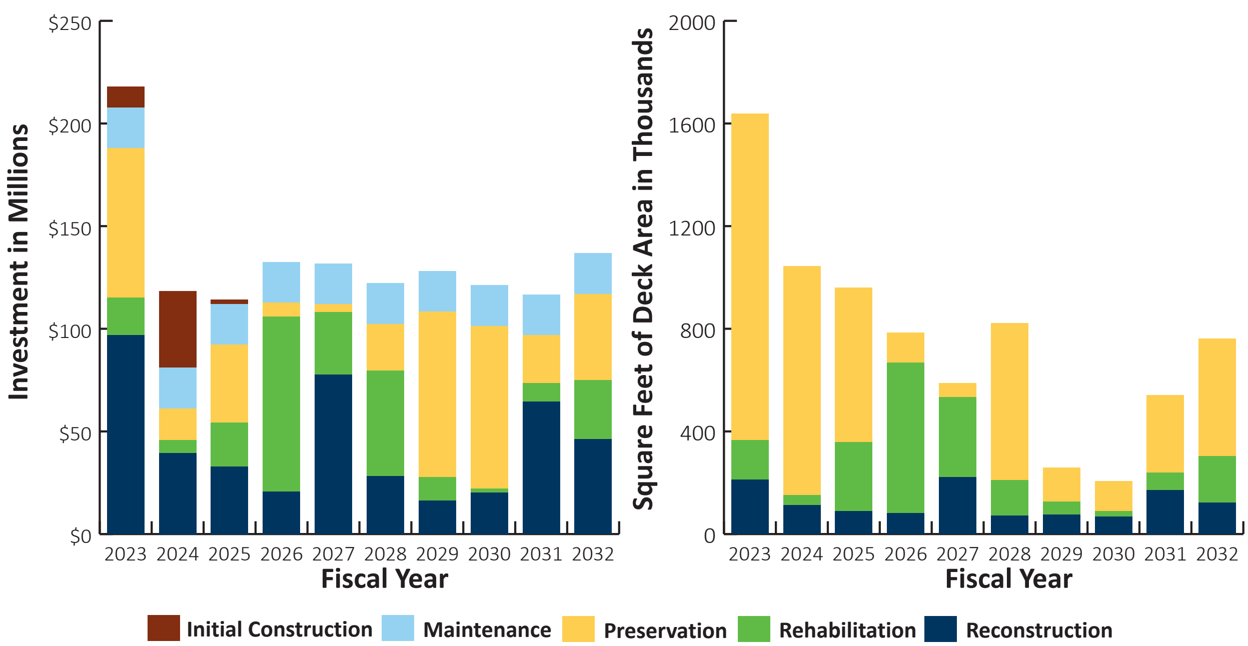


Figure 7-13 and Figure 7-14 show the bridge investment amounts and deck area addressed by work type by system NHS and Non-NHS bridges.

Figure 7-13: Yearly Bridge Investment by FHWA Work Type and by System

INVESTMENT	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Reconstruction	$97 M	$39 M	$33 M	$21 M	$78 M	$28 M	$16 M	$20 M	$65 M	$46 M
Carrying NHS	$68 M	$32 M	$21 M	$2 M	$14 M	$0 M	$1 M	$1 M	$46 M	$24 M
Not Carrying NHS	$170 M	$35 M	$56 M	$158 M	$68 M	$123 M	$41 M	$117 M	$86 M	$124 M
Rehabilitation	$18 M	$6 M	$21 M	$85 M	$31 M	$52 M	$12 M	$2 M	$9 M	$29 M
Carrying NHS	$11 M	$6 M	$0 M	$75 M	$31 M	$51 M	$0 M	$0 M	$0 M	$22 M
Not Carrying NHS	$8 M	$0 M	$21 M	$10 M	$0 M	$1 M	$12 M	$2 M	$9 M	$7 M
Preservation	$73 M	$15 M	$38 M	$7 M	$4 M	$23 M	$80 M	$79 M	$23 M	$42 M
Carrying NHS	$55 M	$14 M	$16 M	$2 M	$3 M	$20 M	$72 M	$74 M	$0 M	$33 M
Not Carrying NHS	$18 M	$1 M	$22 M	$4 M	$1 M	$3 M	$9 M	$5 M	$23 M	$9 M
Maintenance	$20 M	$20 M	$20 M	$20 M	$20 M	$20 M	$20 M	$20 M	$20 M	$20 M
Carrying NHS	$11 M	$11 M	$11 M	$11 M	$11 M	$11 M	$11 M	$11 M	$11 M	$11 M
Not Carrying NHS	$9 M	$9 M	$9 M	$9 M	$9 M	$9 M	$9 M	$9 M	$9 M	$9 M
New Construction	$10 M	$37 M	$2 M	$0 M	$0 M	$0 M	$0 M	$0 M	$0 M	$0 M
Carrying NHS	$10 M	$25 M	$2 M	$0 M	$0 M	$0 M	$0 M	$0 M	$0 M	$0 M
Not Carrying NHS	$0 M	$12 M	$0 M	$0 M	$0 M	$0 M	$0 M	$0 M	$0 M	$0 M
Total	$218 M	$118 M	$114 M	$132 M	$132 M	$122 M	$128 M	$121 M	$117 M	$137 M
Carrying NHS	$155 M	$89 M	$50 M	$91 M	$58 M	$82 M	$84 M	$87 M	$57 M	$90 M
Not Carrying NHS	$63 M	$29 M	$64 M	$41 M	$73 M	$40 M	$44 M	$34 M	$59 M	$47 M

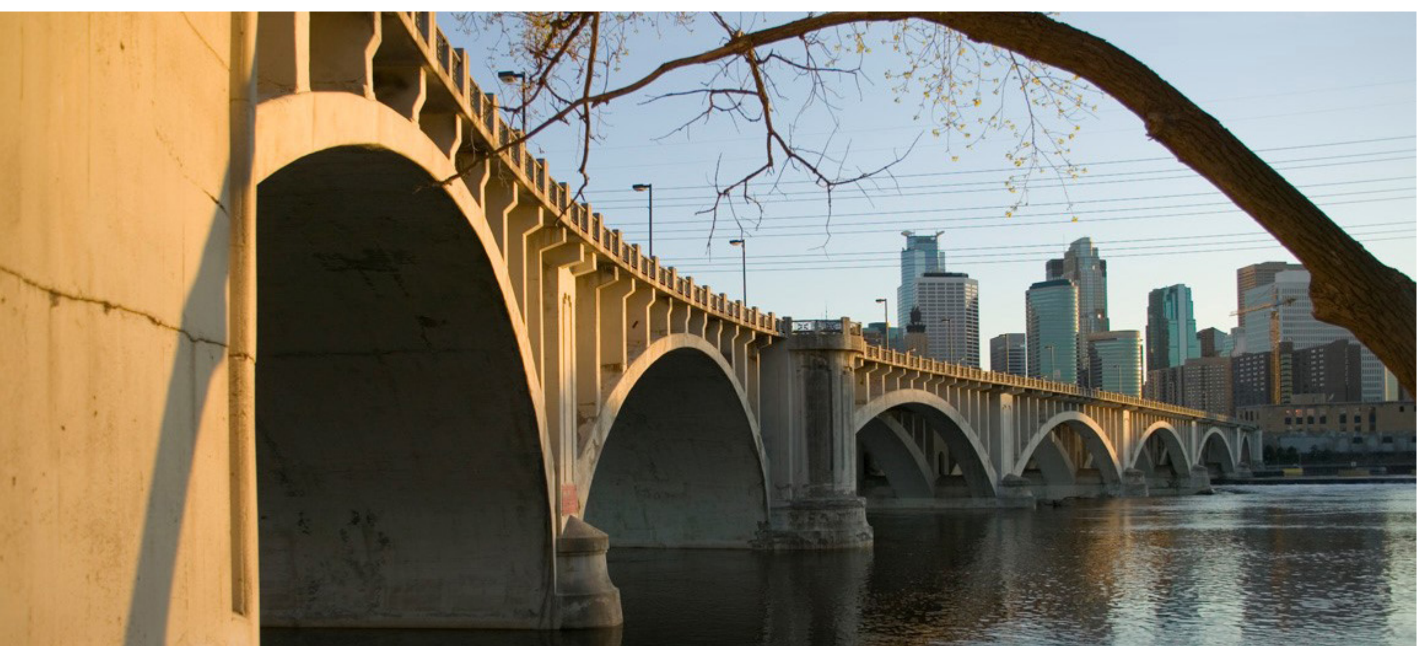


Figure 7-14: Yearly Bridge Square Feet of Deck Area Improved by FHWA Work Type and by System (in thousands unless followed by a M for millions)

Note: Predicted square footage of new construction bridges is unavailable until bridge is constructed.

INVESTMENT	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Reconstruction	211	113	89	81	222	71	75	67	171	122
Carrying NHS	103	84	53	28	173	9	2	6	113	63
Not Carrying NHS	108	29	36	53	49	62	73	61	58	59
Rehabilitation	155	39	268	588	310	140	52	22	68	182
Carrying NHS	68	34	16	476	307	95	15	16	15	116
Not Carrying NHS	86	5	251	112	3	45	37	6	53	66
Preservation	1,274	893	603	116	55	612	132	118	302	456
Carrying NHS	1,031	812	399	66	39	594	0	6	13	329
Not Carrying NHS	243	81	204	50	16	17	132	112	289	127
Maintenance	9,659	9,659	9,659	9,659	9,659	9,659	9,659	9,659	9,659	9,659
Carrying NHS	5,542	5,542	5,542	5,542	5,542	5,542	5,542	5,542	5,542	5,542
Not Carrying NHS	4,117	4,117	4,117	4,117	4,117	4,117	4,117	4,117	4,117	4,117
New Construction	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total	11.3 M	10.7 M	10.6 M	10.4 M	10.2 M	10.5 M	9.9 M	9.9 M	10.2 M	10.4 M
Carrying NHS	6.7 M	6.5 M	6.0 M	6.1 M	6.1 M	6.2 M	5.6 M	5.6 M	5.7 M	6.1 M
Not Carrying NHS	4.6 M	4.2 M	4.6 M	4.3 M	4.2 M	4.2 M	4.4 M	4.3 M	4.5 M	4.4 M

OTHER ASSETS

BUILDINGS

A portion of MnSHIP funding and state bonding for rest areas and weigh stations will be used for on-site improvements that are not building improvements and will not affect building condition. For the 10 years from 2023 to 2032, MnDOT expects annual capital and maintenance expenditure funding of $13 million for buildings and an additional $20 million per year to meet the condition target.

HIGHWAY CULVERTS AND DEEP STORMWATER TUNNELS

For the 10 years from 2023 to 2032, MnDOT expects capital and maintenance funding of $258 million for highway culverts and needs an additional $69 million to meet the poor condition target. Deep stormwater tunnel funding is anticipated to be $7 million and will not need additional investment to reach the target.

ITS INFRASTRUCTURE

Intelligent Transportation Systems are supporting assets on the state highway system, helping to improve efficiency and safety. For the 10 years from 2023 to 2032, MnDOT expects to spend $19.6 million in capital and maintenance funding. ITS assets sometimes receive additional funding from district construction projects or end of year available budget. However, this funding is not included in the calculation as it is inconsistent and varies in the amount received. An additional $241.5 million is needed to meet targets.

NOISE WALLS

Noise walls are a supporting asset on the state highway system. Visual imperfections, such as paint chipping are obvious, the wood post density and panel deterioration drive the need for wall replacement.

For the 10 years from 2023 to 2032, MnDOT expects capital and maintenance funding of $40 million for noise walls. This investment amount is sufficient to meet the noise walls target. Depending on the need, up to 10% of available funding can be used for noise wall preservation activities such as plank/batten repair (loose nails/screws), sealing on concrete posts, etc.

OVERHEAD SIGN STRUCTURES

The investment strategy for overhead sign 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 2023 to 2032, MnDOT expects capital and maintenance funding of $28 million for overhead sign structures and needs an additional $5 million to meet the poor condition target. MnSHIP also outlines several strategies to maximize future Roadside Infrastructure Condition investment:

PEDESTRIAN INFRASTRUCTURE

For the 10 years from 2023 to 2032, MnDOT expects capital and maintenance expenditure funding of $267 million for curb ramps and sidewalk compliance and would need an additional $229 million to meet the Americans with Disabilities Act compliance targets.

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

TRAFFIC SIGNALS AND LIGHTING

Traffic signals and lighting are supporting assets on the state highway system. For the 10 years from 2023 to 2032, MnDOT expects capital and maintenance funding of $162 million for signals and needs an additional $387 million to meet the poor condition target. Likewise, MnDOT expects capital and maintenance funding of $126 million for lighting and needs an additional $100 million to meet the poor condition target.

HIGH-MAST LIGHT TOWERS

The 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 2023 to 2032, MnDOT expects capital and maintenance funding of $4 million for high-mast light towers and needs an additional $1 million to meet the poor condition target.

SUMMARY

MnDOT's current investment approach is focused on maintaining existing assets on the state highway system. Despite this investment focus, conditions for many assets are not expected to meet their performance targets in 10 years. Asset management needs continue to exceed available funding. The investment strategies and life cycle planning for the TAMP help provide the greatest benefits possible for state highway assets.

TAMP IMPLEMENTATION

The Minnesota Department of Transportation is committed to implementing the Transportation Asset Management Plan and continually improving the management of the transportation system. MnDOT demonstrates its commitment through investment in organizational, data and technology resources. Significant highlights include:

- MnDOT employs executive asset management governance. The agency established an Asset Management Steering Committee in 2015 to set strategic direction and priorities. It deals with data acquisition and maintenance, technology systems and tools, investment plan integration, performance measures and accountability. Membership includes the Assistant Commissioners for Modal Planning and Program Management, Operations, and Engineering Services, in addition to several other departmental roles. The team meets monthly and is chaired by the Asset Management Program Office manager.
- In 2015, MnDOT created the Asset Management Program Office to lead all implementation tasks. The team is responsible for planning, central coordination of asset data, managing all facets of the Transportation Asset Management System, data analysis services, support of TAMP preparation and the coordination between maintenance and operations planning and MnDOT's capital planning efforts. This nine-person team has wide-ranging expertise, including three IT professionals.
- In 2021, MnDOT created a dedicated Asset Management section in the Office of Bridges and Structures. Under the direction of an Administrative Engineer Professional, this section is responsible for managing all bridge inventory and condition data, managing the active development of software and support tools, and conducting investment analysis, including capital investment scenarios. The section also integrates MnDOT's capital and maintenance investment strategies through the work of the Bridge Preservation Engineer, who establishes best practices, performance measures and targets, and tracking systems for MnDOT's maintenance workforce.
- MnDOT follows an inclusive and collaborative process in the development of its TAMP. Approximately a dozen teams contribute their expertise in specific asset class management, field operations, planning and other disciplines when evaluating and recommending process improvements through the TAMP. This inclusive approach significantly enhances the understanding and commitment to asset management practices.
- MnDOT's Office of Transportation System Management leads the development of both MnDOT's 20-Year State Highway Investment Plan and its TAMP. Several of the office's personnel are involved with both plans, yielding synergy between the efforts. Both plans are being updated simultaneously during 2022.

- MnDOT has invested heavily in management systems to support asset investment decision-making. It has operated the Highway Pavement Management Application for numerous years, which will transition to the TAMS platform in early 2023. MnDOT's custom built Bridge Replacement and Improvement Management tool interacts with American Association of State Highway and Transportation Officials' Bridge Management Software and Bentley's Inspect AssetWise systems.
- MnDOT implemented TAMS in 2015. The system is used by 2,000 MnDOT employees, houses asset inventory data for a dozen asset classes (1.2 million asset records) and is a robust platform for tracking work, costs and outcomes for much of the asset-related work MnDOT performs.
- MnDOT employs robust asset-related data management practices. The MnDOT Bridge and Materials and Road Research Offices are responsible for complying with bridge and pavement data requirements, respectively. The agency has established a strategic plan for the acquisition and management of data for approximately 70 roadside assets, as well as other asset classes. MnDOT operates a data governance structure overseeing seven data domains, one being "Infrastructure." The objective is to ensure that data is treated as a valuable asset and managed accordingly.
- While MnDOT operates in a decentralized decision-making structure, it benefits from collaboration between district "asset owners," who make and execute investment decisions, and Central Office "asset managers," who provide analysis, guidance and best practice support.

ASSET MANAGEMENT STRATEGIC IMPLEMENTATION PLAN

In 2020, MnDOT developed an Asset Management Strategic Implementation Plan to increase the understanding and engagement of district decision-makers and practitioners and chart an orderly course for data acquisition and maintenance. Features of the plan, adopted in 2021, include the acquisition and maintenance of asset data, ensuring execution of preventive maintenance strategies through measures and targets, a communications plan to enhance agency engagement and strategies to maximize the usefulness of this TAMP.

Considerable work on implementing the AMSIP has been completed since the beginning of the AMSIP process. MnDOT has developed a geotechnical asset inventory, executed a high-impact communications plan, implemented the preventive maintenance performance measures and practices.

FUTURE IMPLEMENTATION

Two major sources of MnDOT's planned advancements for asset management derive from AMSIP and workgroup recommendations resulting from the TAMP's preparation. The AMSIP contains numerous recommendations that will be worked on over the next four years, such as:

ASSET DATA

- Use office staff to digitize existing data to create additional inventories.
- Use a consultant contract to update sign and other asset inventories statewide.
- Catch up on lagging As-Built Data.

- Add attribution to Geotech asset inventory elements.
- Facilitate and document “Roles and Responsibilities.”

COMMUNICATIONS

- Continue to execute the communications plan by expanding it to Central Office personnel.
- Continue to develop the communications web portal to make reference materials easil available.

TAMP

- Develop additional asset folios between TAMP version.
- Develop (or enhance) GIS tools to better coordinate long-range planning, program tradeoff decisions, scoping and design decisions.

TAMP WORKGROUPS

Development of the TAMP involved 10 subject matter expert teams. As a part of a risk assessment and general management practices review, each team proposed numerous process improvements. High-level examples of priority business process improvements and research proposal items include:

BUSINESS PROCESS IMPROVEMENTS

PAVEMENT

- Consider climate, vulnerability, sustainability and mitigation measures in project scoping.
- Change design (or over-design) according to better projections (e.g., VMT, HCVMT, ESALs, environmental factors).

BRIDGE

- Fully implement an element-level based bridge performance measures.
- Fully implement bridge preventive maintenance performance measures.
- Implement “Bridge Watch” in conjunction with the flood vulnerability model to alert maintenance of potentially impacted or vulnerable bridges.
- Identify “repeat” bridge hit locations and install devices or technologies to help prevent bridge hits.

BUILDINGS/FACILITIES

- Complete initiatives identified in the 2019 TAMP
    - Building/Facilities Assessment
    - Buildings/Facilities ADA Assessment
- Facilities Space and Security Assessments

HYDRAULICS

- Advance district use of TAMS functionalities, including decision trees for scoping and repair planning.

INTELLIGENT TRANSPORTATION SYSTEMS

- Develop and document a consistent process for gathering the cost and expenditures for assets.
- Communicate the financial need and develop and track uptime performance measures.
- Standardize certain materials rather than customizing them based on locations.
- Develop workflows to identify the appropriate responsible party for maintenance/operations.

NOISE WALLS

- Change to the 9-point rating with 4-point element rating to align with other assets.
- Use TAMS data for annual FHWA reporting.

OVERHEAD SIGNS

- Integrate all data into TAMS, which includes inventory and condition data.
- Implementation of the Nut Tightening Project.
- Post clips for overhead signs, which considers material changes, inspection frequency and maintenance impacts.

PEDESTRIAN FACILITIES

- Develop an inspection cycle protocol based on condition or age data in TAMS.
- Delineate separated bicycle lanes for individuals with visual disabilities.

TRAFFIC SIGNALS AND LIGHTING

- Develop a statewide signal and lighting checklist for construction.
- Develop fully dependable inventory and condition data for lighting and signals per AMSIP recommendations.

FUTURE RESEARCH

PAVEMENT

- Better understand the performance of pavement rehabilitation (including preventive maintenance) treatments in relation to asset age and condition.
- Study cost-benefit to treat ancillary pavements as separate assets, independent of mainline, and use different measures, deterioration models, data collection, etc.
- Determine if results from Satellite Pavement Imagery research can be put into practice for the management of ancillary pavements such as ramps and loops.
- Integrate user cost models into the pavement management system so that computations can be performed within the system.

BRIDGE

- Research process for predicting future condition using an element-level based bridge rating system to develop investment optimization strategies and possible performance targets.
- Research effectiveness of bridge maintenance activities and establish benefit-cost ratios so that activities with highest ratios can be prioritized.

BUILDINGS/FACILITIES

- Consider advanced deterioration from different materials (liquid brine).
- Look into how larger trucks could impact truck stations.
- Evaluate electric vehicle impacts on facilities.

HYDRAULICS

- Continue development of deterioration models for various types of culverts and tunnels.
- Research different rehabilitation methods to provide enhanced design guidance and new tools for pipe repair.
- Research pipe design guidance to determine what is causing early failures.
- Improve the design and use of pipes and structures.

INTELLIGENT TRANSPORTATION SYSTEMS

- Undertake more obsolescence planning.

NOISE WALLS

- Study how roadway proximity may predict deterioration rates.
- Explore noise wall alternatives like steel posts and concrete panels that may reduce maintenance material and installation costs.

OVERHEAD SIGNS

- Develop deterioration models and more accurate average service life.
- Better understand the impacts of preventive maintenance performed on these structures at varying ages and conditions.

PEDESTRIAN FACILITIES

- Assess the deterioration rate of pedestrian assets to identify an accurate sidewalk and ramp life cycle.
- Determine how to recognize and account for mid-life cycle treatments, such as panel replacements.

TRAFFIC SIGNALS AND LIGHTING

- Analyze TAMS data by using a consultant to determine best practices for predictive versus reactive maintenance.
- Evaluate and compare smart lighting systems in Metro District (e.g., power usage, dimming and turning lights on or off).

MnDOT will use this guidance to continually advance its asset management maturity by working through its governance structure to prioritize and commit available resources.

CONCLUSION

MnDOT's 2022 TAMP development has improved and refined many aspects of the agency's policies and methods related to asset management. Improvements include more robust life cycle planning for all assets, a broader examination of risk management, and strengthened communication with asset experts, non-state owners of the National Highway System and agency leaders. These steps solidify the objectives and vision of asset management at MnDOT and bolster efforts to enhance financial effectiveness, improve policy and programming decisions and help the agency meet the high standard of service expected by the traveling public.

APPENDIX A - RISK TIERS AND GLOSSARY

Figure A-1: Risk Mitigation Priorities Tier One by Asset Type, 1 of 2

RISK CODE	TIER ONE RISK MITIGATION PRIORITIES	RISK PRIORITY	RISK REDUCTION	COST SCORE	TOTAL SCORE
1P	Pavements: Provide better training for construction inspectors. Change design (or over-design) according to better projections (VMT, HCVMT, ESALs, environmental factors)	1	3	3	7
2P	Pavements: Use various tools to communicate the need/ benefit of following the lowest LCP strategy by implementing a regular pavement management schedule	3	3	1	7
3P	Pavements: Identify alternative revenue sources due to reductions from various sources resulting from technological changes. Continue to research how to optimize MnDOT's dollars	3	3	1	7
4P	Pavements: Study cost-benefit of treating ancillary pavements as separate assets independent of mainline using different measures, deterioration modeling, data collection, etc.	2	4	3	9
1B	Bridges: Improve design and construction practices	1	2	1	4
2B	Bridges: Dedicate full-time inspectors and staff with proper training. Focus more quality assurance and training resources to state-owned system	2	4	1	7
3B	Bridges: Expand practices to identify more shelf-projects that can be addressed with more funding. Lobby for more funding and better communicate funding needs. Tie expansion projects to maintenance budgets	3	4	1	8
1BLDG	Buildings: Develop a plan for data collection and maintenance	1	4	1	6
4BLDG	Buildings: for Funding: Implement the Facilities Asset Management Plan	3	4	4	11
1HCDST	Culverts and Deep Stormwater Tunnels: Inspect tunnels according to inspection schedules (local jurisdictions conduct inspections on tunnels with shared water)	2	1	1	4
2HCDST	Culverts and Deep Stormwater Tunnels: Rehab culverts before failure occurs and make permanent fixes during future pavement projects	1	3	1	5
3HCDST	Culverts and Deep Stormwater Tunnels: Better model and research deterioration. Address culvert needs earlier in pavement project scoping-- (e.g., during STIP/CHIP development)	1	4	1	6
4HCDST	Culverts and Deep Stormwater Tunnels: Perform regular Inspections and invest in recommended repairs (follow ideal LCP strategy)	1	1	5	7

Figure A-1: Risk Mitigation Priorities Tier One by Asset Type, 2 of 2

RISK CODE	TIER ONE RISK MITIGATION PRIORITIES	RISK PRIORITY	RISK REDUCTION	COST SCORE	TOTAL SCORE
5HCDST	Culverts and Deep Stormwater Tunnels: Collect statewide location inventory and inspection data of storm drains	2	1	5	8
6HCDST	Culverts and Deep Stormwater Tunnels: Communicate funding needs. (e.g., more cost-effective to align culvert replacement with pavement projects; emphasize this approach as an optimization strategy)	3	4	1	8
1ITS	Intelligent Transportation Systems: Communicate funding needs. Develop and track performance measures	3	3	2	8
1NW	Noise Walls: Annually collect asset inventory and condition data using LiDAR. Maintain a regular inspection schedule to collect data that LiDAR cannot capture. Inspect noise walls at appropriate frequencies to promptly address fixes	2	2	3	7
2NW	Noise Walls: Consider noise walls earlier in scoping process to include them in project costs	3	3	1	7
3NW	Noise Walls: Set up work plans for walls based on their age and condition	1	4	3	8
1OS	Overhead Signs: Inspect every five years using a standard inspection form to identify overhead signs that may require more frequent inspections. Revise standards (e.g., MnDOT previously used grout but found it led to premature deterioration)	1	4	1	6
2OS	Overhead Signs: Identify when sign panel sizes are outside of standards. Verify with engineer the use of current design specifications in standard plans	4	2	1	7
3OS	Overhead Signs: Train installers and certify inspectors. Ensure construction inspections are done correctly and any construction flaws are fixed	4	1	2	7
1PED	Pedestrian Infrastructure: Collect pedestrian assets using mobile LiDAR	2	2	3	7
2PED	Pedestrian Infrastructure: Develop and pilot performance measures for maintaining pedestrian facilities in partnership with local jurisdictions. Identify consistent maintenance approaches to better define responsibilities included in maintenance agreements under cooperative agreements and in master maintenance agreements	1	4	3	8
1SLHMT	Traffic Signals, Lighting, and High-Mast Light Towers: Ensure adequate staffing for structural inspection throughout asset life cycle. Develop life cycle replacement or preservation program for standalone projects	1	1	1	3
2SLHMT	Traffic Signals, Lighting, and High-Mast Light Towers: Document and communicate needs (e.g., business plans)	3	3	1	7

Figure A-2: Risk Mitigation Priorities Tier Two by Asset Type, 1 of 2

RISK CODE	TIER TWO RISK MITIGATION PRIORITIES	RISK PRIORITY	RISK REDUCTION	COST SCORE	TOTAL SCORE
5P	Pavements: Significant damage to the asset through human-made or natural events	4	4	2	10
4B	Bridges: If premature replacement due to widening is necessary, communicate loss of service life costs and how it impacts projections	5	4	1	10
2BLDG	Buildings: ***Rest areas and headquarters:*** Include Americans with Disabilities Act assessment information in project selection criteria. ***All buildings:*** Identify communication gaps and find a way to address them	4	4	2	10
3BLDG	Buildings: Develop a plan for data collection and maintenance	2	5	3	10
5BLDG	Buildings for Competing Stakeholder Expectations: Implement the Facilities Asset Management Plan	6	4	1	11
7HCDST	Culverts Deep Stormwater Tunnels: Formalize the process of checking hydraulic capacity and the availability of existing culvert storage when deciding whether to line it. Keep track of culverts in areas with flooding problems to determine if they need repair	4	2	3	9
8HCDST	Culverts Deep Stormwater Tunnels: Add recommended tunnel capacity	4	1	5	10
9HCDST	Culverts Deep Stormwater Tunnels: Complete location inventory, continue current inspections and identify damage and repair needs	4	2	5	11
2ITS	Intelligent Transportation Systems for Infrastructure Resilience: Update standards in design manual and provide training on standards. Create a construction manual and provide certification training. Create an operations and maintenance manual and provide training	4	4	3	11
3ITS	Intelligent Transportation Systems for Succession Planning: Update standards in the design manual and provide training on standards. Create a construction manual and provide certification training. Create an operations and maintenance manual and provide training	7	1	3	11
4ITS	Intelligent Transportation Systems: Develop workflows	8	2	1	11
4NW	Noise Walls: Set cyclical repair either as part of the inspection process or from TAMS recommendations	8	2	1	11
4OS	Overhead Signs: Develop a new response process and make sure it is well understood by all parties. (Continue to focus on response due to an inability to predict these events)	4	3	1	8
3PED	Pedestrian Infrastructure: Fully integrate assets into TAMS work order process. Develop MnDOT guidance on best practices for maintenance of pedestrian assets	1	3	4	8
3SLHMT	Signals, Lighting, and High Mast Light Towers: Continue to follow through and fully implement "in-process" mitigation strategies. Have trained inspectors inspect assets during construction	4	1	4	9

Figure A-2: Risk Mitigation Priorities Tier Two by Asset Type, 2 of 2

RISK CODE	TIER TWO RISK MITIGATION PRIORITIES	RISK PRIORITY	RISK REDUCTION	COST SCORE	TOTAL SCORE
4SLHMT	Signals, Lighting, and High Mast Light Towers: Increase resources to respond to incidents more quickly (there are several options for prevention, but none that are based on competing factors)	4	3	3	10
5SLHMT	Signals, Lighting, and High Mast Light Towers: Use more secure passwords (Cybersecurity mitigation provided through MNIT). Add locks to cabinets, mostly done through vendors	8	1	1	10
6SLHMT	Signals, Lighting, and High Mast Light Towers: Need dedicated statewide construction inspectors trained in signals and lighting (e.g., electrical components)	4	4	3	11

Figure A-3: Risk Mitigation Priorities Tier Three by Asset Type, 1 of 2

RISK CODE	TIER THREE RISK MITIGATION PRIORITIES	RISK PRIORITY	RISK REDUCTION	COST SCORE	TOTAL SCORE
6P	Pavements: Create a vocational program for highway technicians. Improve tech certification program by working with industry to improve outreach	7	4	1	12
7P	Pavements: Educate the public on what it takes to maintain the roads. (e.g., surface rating vs. the structure itself, what it takes to maintain roads and what jurisdiction is responsible)	6	4	4	14
5B	Bridges: Identify and prioritize bridges in need of debris removal. Use flood vulnerability model output to prioritize areas in need of further checking criticality/loss of structure. Implement Bridge Watch, a GIS-based predictive program for rain events and how they impact existing infrastructure. Bridge Watch sends alerts to maintenance crews to identify bridges that may be impacted	4	4	4	12
6B	Bridges: Improve recruiting practices, change job requirements for certain positions and improve cross-training	7	4	1	12
7B	Bridges: Identify critical elements, increase the inspection/ monitoring frequency, including better access for equipment and traffic control	4	4	5	13
8B	Bridges: Identify which assets have had repeat hits and are considered high-risk. Install warning systems and cameras at high-risk locations (lower cost option than re-placements) or Meet standards for high-risk locations be-fore planning replacements	4	4	5	13
9B	Bridges: Understand proposals, identify what challenges they pose and make changes accordingly	8	4	1	13
10B	Bridges: Receive adequate funding to fully implement the current mitigation strategy. Base federal targets on an element-level approach	6	5	5	16
11B	Bridges: Fully implement using element-level based bridge performance measures and preventive maintenance performance measures	8	4	5	17

Figure A-3: Risk Mitigation Priorities Tier Three by Asset Type, 2 of 2

RISK CODE	TIER THREE RISK MITIGATION PRIORITIES	RISK PRIORITY	RISK REDUCTION	COST SCORE	TOTAL SCORE
6BLDG	Buildings: Design based on truck station standards manual	7	4	1	12
7BLDG	Buildings: Identify communication gaps and address them	8	4	2	14
5ITS	Intelligent Transportation Systems: Add more details into requests for proposals to ensure support and reliability when selecting potential vendors	7	4	1	12
6ITS	Intelligent Transportation Systems: Create plans to address potential obsolescence	8	4	1	13
7ITS	Intelligent Transportation Systems: Standardize certain materials rather than customizing based on location	8	4	2	14
5NW	Noise Walls: Fund aesthetics based on performance-based paint specifications (alternatively, MnDOT will prioritize additional funding through other means unless there is dedicated aesthetic funding)	6	4	5	15
5OS	Overhead Signs: Train and hire staffing concurrently. Fostering consistent documentation standards across districts	7	4	1	12
6OS	Overhead Signs: Pilot new technology with experimental projects before widespread implementation	8	5	5	18
4PED	Pedestrian Infrastructure: Increase capacity among existing staff and hire additional staff at the district level	7	1	4	12
5PED	Pedestrian Infrastructure: Continue current control and mitigation strategies. Incorporate 3D modeling to improve planning, design and construction	4	4	5	13
6PED	Pedestrian Infrastructure: Implement the master maintenance agreements	7	4	3	14
7PED	Pedestrian Infrastructure: Develop performance measures based on location, type of repair and response timeframe to address complaints. Identify trends to support a more proactive approach	6	4	4	14
7SLHMT	Signals, Lighting, and High Mast Light Towers: Modernize tunnel lighting by providing backup power systems (focus on tunnels due to more critical safety risks). Communicate to the traveling public when systems are out of operation	7	3	2	12
8SLHMT	Signals, Lighting, and High Mast Light Towers: Continue to upgrade equipment to the central system. Follow life cycle management strategy on all equipment to minimize failures	5	4	5	14
9SLHMT	Signals, Lighting, and High Mast Light Towers: Follow life cycle management strategy on all equipment to minimize failures	5	4	5	14
10SLHMT	Signals, Lighting, and High Mast Light Towers: Implement signal timing performance measures (e.g., retime on-demand, as needed)	8	4	3	15

RISK MANAGEMENT GLOSSARY

Adaptation - anticipation of, or response to, a changing environment in a way that effectively uses beneficial opportunities or reduces negative effects.

Climate Change - any significant change in the measures of climate lasting for an extended period of time. Climate change includes major variations in temperature, precipitation, or wind patterns, among other environmental conditions, that occur over several decades or longer. Changes in climate may manifest as a rise in sea level, as well as increase the frequency and magnitude of extreme weather events now and in the future.

Consequence - outcome of an event affecting objectives

Event - occurrence or change of a particular set of circumstances

Extreme Weather Events - significant anomalies in temperature, precipitation and winds and can manifest as heavy precipitation and flooding, heatwaves, drought, wildfires and windstorms (including tornadoes and tropical storms). Consequences of extreme weather events can include safety concerns, damage, destruction, and/or economic loss. Climate change can also cause or influence extreme weather events.

Likelihood - chance of something happening

Monitoring - continual checking, supervising, critically observing or determining the status in order to identify change from the performance level required or expected

Resilience/Resiliency - the ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions

Risk - effect of uncertainty on objectives

Risk Analysis - process to comprehend the nature of risk and to determine the level of risk

Risk Assessment - overall process of risk identification, risk analysis and risk evaluation

Risk Appetite - The types and amount of risk, on a broad level, an organization is willing to accept in pursuit of value

Risk Identification - process of finding, recognizing and describing risks

Risk Management - coordinated activities to direct and control an organization with regard to risk

Risk Owner - person or entity with the accountability and authority to manage a risk

Risk Management Plan - scheme within the risk management framework specifying the approach, the management components and resources to be applied to the management of risk

APPENDIX A - RISK TIERS AND GLOSSARY

Risk Management Policy - statement of the overall intentions and direction of an organization related to risk management

Risk Management Process - systematic application of management policies, procedures and practices to the activities of communicating, consulting, establishing the context, and identifying, analyzing, evaluating, treating, monitoring and reviewing risk

Risk Treatment - process to modify risk

Uncertainty - the state, even partial, of deficiency of information related to, understanding or knowledge of an event, its consequence, or likelihood

Vulnerability - weaknesses or gaps in risk management efforts

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APPENDIX B - TAMP RISK REGISTER

Figure B-1: Pavement Asset Risk Register, 1 of 2

RISK CODE	RISK CATEGORY	RISK	CURRENT MITIGATION STRATEGY	GAP	IDEAL MITIGATION STRATEGY	RESOURCES NEEDED
1P	Aging Infrastructure	Premature deterioration of pavements (e.g., construction issues, increase in traffic, higher equivalent single axle loads (ESALs) and snow and ice removal methods)	Improve asphalt and concrete mixes. Improvement in ice removal practices. Use of HPMA in decision-making for projects. Have tested use of salt alternatives and practices that reduce the amount of salt needed. Improve traffic modeling for more accurate ESAL data. Apply PM. VMT reduction targets	Funding trade-offs. Technology transfer. Inconsistencies across department. Lack of expertise of construction inspectors in the industry.	Better training for construction inspectors. Change design (or over-design) according to better projections (e.g., VMT, HCVMT, ESALs, environmental factors)	Use tech certification program to implement better training. Address rutting problems of automated vehicles. Focus on reducing HCVMT, as trucks result in the most damage or change in how we plan for truck/freight travel. Over-designing to account for unknowns requires additional funding to reduce this risk
2P	Funding	Inability to manage to the lowest life cycle cost	Better understanding of impact and more implementation of PM. Improved products/materials used for PM. Improved options for fixes in all work types. Improved LCP analysis to better understand LCC scenarios	Funding constraints. Current programming practices limit our ability to follow lowest LCC. Decline in reconstruction of rural pavements (doing more rehab instead). Political pressure prioritizes projects outside of an ideal LCP strategy. Other competing priorities (ex major bridge projects)	Use various tools to communicate the need/ benefit of following the lowest LCP strategy by implementing a regular pavement management schedule	Use different overall network strategy for different roads (ex. low vs high volume roads). Use new health indicators that are being developed. Increase in pavement funding needed
3P	Funding	Significant reduction in funding over time	Investment scenario planning. Trying to be more efficient by using more optimization strategies. Applying shorter-term fixes. Improving specifications, design, etc. Advanced understanding of what the reduction will be to better plan projects	Don't correctly tell the story the impact of reduced funding has on the condition of our system. Change in vehicle design has changed public perception of pavement condition	Identify alternative revenue sources due to reductions from various sources resulting from technological changes. Continue to research how to optimize MnDOT's dollars	Good leadership and industry support (already doing well). Annual report to legislature to communicate pavement condition/need. Maintain research and implementation funding
4P	Data Management/ Lack of Data/ Quality of Data	Low prioritization of ancillary pavements (e.g., frontage roads, ramps, auxiliary lanes and rest areas)	N/A (Ancillary pavement condition using satellite imagery project.) Rest areas are addressed differently: collected condition of rest area pavements and included in MnSHIP investment need. some rest areas have been funded through freight program for site improvements	Lack of inventory and condition data for ancillary pavements. Have collected this data in the past, but a big need for this data has not been identified. Treat them differently when addressing mainline project	Study cost-benefit of treating ancillary pavements as separate assets independent of mainline using different measures, deterioration modeling, data collection, etc	Identify potential turn-backs. Rest areas to use different metric than other ancillary pavements. Identify need early enough in scoping to be able to include in need. Treat them as standalone projects and include in budget trade-offs. Collect data, develop deterioration models, etc. (may not be worthwhile). We currently focus on mainline, and likely won't address these until those are addressed
5P	Infrastructure Resilience	Significant damage to the asset through human-made or natural events	Preventive maintenance. Federal ER requirement (analysis to see if there are locations with repeat damage due to extreme weather events). Districts have BARC funds which may be used to address emergencies. Climate change studies. Maintenance fixes quickly after an event to reduce system disruption. Slope vulnerability project	Risks addressed during projects but need more focus on more proactive understanding system-wide. Implementation of slope vulnerability model	Include potential needs in scoping (climate models, slope vulnerability analysis, emergency response history, etc.). Identify a separate pot of money to address reactive needs. Better study these events and learn how to mitigate them. Study more resilient designs	Training on available tools. Look at historic spending on reactive activities to predict future needs, and increase BARC funds accordingly. Recommend using climate modeling when completing an ER project to build a more resilient system rather than replacing in-kind. Research proposals

Figure B-1: Pavement Asset Risk Register, 2 of 2

RISK CODE	RISK CATEGORY	RISK	CURRENT MITIGATION STRATEGY	GAP	IDEAL MITIGATION STRATEGY	RESOURCES NEEDED
6P	Succession Planning	Losing construction experience through attrition	Aggressive training program for new techs. Centralized federally required technician certification program using adult learning techniques. Hired additional staff for plant monitoring. Plan to hire more staff for construction	Lack of expertise of construction inspectors in the industry. Takes many years to develop necessary expertise. TW (transportation worker) staff series has limited our ability to get qualified applications. No vocational program for highway technicians	Create a vocational program for highway technicians. Improve tech certification program by working with industry to improve outreach	Work with staff we hired to develop outreach program. Need more help from MMB for outreach to underrepresented groups. Highway technician testing Raise pay of technicians and engineers in the industry to incentivize interest in the field. Education that this field exists. MnDOT to increase STEM outreach (ex through ASCE)
7P	Competing Stakeholder Expectations	Not meeting public expectations for pavement quality/ condition (state, district and local levels)	Increased percent of pavements in good condition	Understanding expectations of the public	Educate the public on what it takes to maintain the roads. (e.g., surface rating vs. the structure itself, what it takes to maintain roads and what jurisdiction is responsible)	Used to have a market research staff, could hire another continue to survey the public to understand their expectations use creative techniques (ex. Minnesota GO stickers to scan and go to informational video, short videos, interactive displays, infographics, roadway condition simulator, etc.) Work with lobbying groups/advocates (Mn Transportation Alliance, LRRB, etc)

Figure B-2: Bridge Asset Risk Register, 1 of 2

RISK CODE	RISK CATEGORY	RISK	CURRENT MITIGATION STRATEGY	GAP	IDEAL MITIGATION STRATEGY	RESOURCES NEEDED
1B	Aging Infrastructure	Premature deterioration of the asset (e.g., service lives that are 10% to 20% shorter than expected, material defects, quality of initial construction)	Quality assurance training for bridge construction inspectors. Implementing innovative best practices into standards. Best Practices and training for maintenance activities. Developed sub-committee to help implement best practices to track trials (look at different types of materials, performance, processes, etc.) Existing related research projects	Inexperienced construction inspectors, lack of understanding of what contributes to premature deterioration, material defects	Improve design and construction practices	Bring maintenance perspective into structural standards review committee. Invite maintenance staff into construction project reviews and involve maintenance into project decision concerns that may impact long-term performance. Better understanding of deterioration. Greater emphasis on workmanship before opening up to traffic.
2B	Data Management/ Lack of Data/ Quality of Data	Poor inspection data, improper data stewardship and software limitations	Created business plan to identify need to develop an improved bridge asset management process (plan to develop new health index, etc.). State-aid staff provide inspection QA on local system	Don't have the plan developed yet for how we will execute a new bridge asset management process	Dedicate full-time inspectors and staff with proper training.	Readjusting workload, position descriptions, and organization structure of existing staff. Hard to attract inspection staff when they are required to also plow snow.
3B	Funding	Lack of, deferred, or inconsistency of funding (e.g., unexpected budget cuts)	Transparency with project selection. Financial scenario planning in place. Selecting high benefit to cost ratio projects. We identify shelf-projects that we would address with more funding	Working toward a more automated scenario planning process. Improvement needed of communicating funding needs to legislature and stakeholders.	Expand practices to identify more shelf-projects that can be addressed with more funding. Lobby for more funding and better communicate funding needs. Tie expansion projects to maintenance budgets	Need more staff to manage to lowest life cycle cost, especially as we expand our system.
4B	Multimodal Safety	Requests or the ability to widen bridges to accommodate multimodal transportation	Practical based performance design to come up with most efficient compromise. outreach to talk to other stakeholders to understand variety of needs.	Not maximizing trade-offs. prioritizing locations that most benefit public and quantifying that benefit. understanding needs early on in project development process. trade-off of increased service vs preservation	If premature replacement due to widening is necessary, communicate loss of service life costs and how it impacts projections	Communicate to all stakeholders. Quantify maintenance impact (ex. closing lanes, safety, user impact, etc.). Trade-off analysis

Figure B-2: Bridge Asset Risk Register, 2 of 2

RISK CODE	RISK CATEGORY	RISK	CURRENT MITIGATION STRATEGY	GAP	IDEAL MITIGATION STRATEGY	RESOURCES NEEDED
5B	Infrastructure Resilience	Unanticipated service interruption due to natural event (e.g., flood, earthquake, adverse weather)	Bridges rated for scour. If they are scour critical, they have a plan of action. BRIM uses scour in the risk prioritization score. Scour protection in place through operational plans. Research on impacts of climate change	Uncertainty of climate change	Identify and prioritize bridges in need of debris removal. Use flood vulnerability model output to prioritize areas in need of further checking criticality/loss of structure. Implement Bridge Watch, a GIS-based predictive program for rain events and how they impact existing infrastructure. Bridge Watch sends alerts to maintenance crews to identify bridges that may be impacted	Crews understand bridges/ bridge culverts that often require debris removal and prioritize them, but many locations that need debris removal are postponed. Flood vulnerability model is not yet complete (additional consultant work is needed) Pursuing a grant to purchase Bridge Watch
6B	Continuity of Operations	Shortage of workforce, lack of qualified replacement candidates (e.g., early retirements and hiring freezes)	STEM outreach, better recruitment, mobilities for cross-training, internship opportunities, TROPS (training opportunities) and bridge maintenance academy	Still not reaching all audiences, recruitment communication, pay inequities compared to general industry, lack of communicating additional benefits beyond pay. Pay inequity	Improve recruiting practices, change job requirements for certain positions and improve cross-training	Make job postings more widely available. Change hiring practices to not require snow plowing with certain maintenance and operations positions. Improve cross-training (mobilities, etc.). Provide clear paths for advancement (mostly, TS)
7B	Infrastructure Resilience	Unanticipated service interruption due to asset condition	Compliant with all FHWA bridge inspection metric requirements. Consistent staff training on inspection process. Increased inspection frequency on poor condition bridges. Increased Program Administrator review process (review and approve inspection reports - can identify critical areas sooner to eliminate service interruption)	Inexperienced inspection staff. Limited access	Identify critical elements, increase the inspection/monitoring frequency, including better access for equipment and traffic control	Consider access for inspection and maintenance throughout entire design process. Understanding critical elements, which are vulnerable, and allocate more money towards them
8B	Infrastructure Resilience	Unanticipated service interruption due to human-caused events (e.g., crashes, damage from construction activities)	Developing standards around repair projects to improve safety requirements. Thorough process for after-incident responsibilities. Raise high-risk assets that have had multiple hits in the past. Meeting standards when assets are replaced: redundancy, safety barrier, and proper vertical and horizontal clearance. Install warning systems for certain construction projects	Unpredictability in behavior of the traveling public. Not enough funding to upgrade bridge assets to current safety design standards	Identify which assets have had repeat hits and are considered high-risk. Install warning systems and cameras at high-risk locations (lower cost option than replacements) OR Meet standards for high-risk locations before planning replacements	Develop tracking system for bridge hits, and regularly update. Also, study adjacent bridges. Identify if there is a pattern or random occurrences. Document findings as a tool for decision-making. Quickly respond to incidents to reduce system interruption times
9B	Response to Disruptive Transportation Technologies	Autonomous trucking legislation and an increase in truckload capacity may increase the design load for bridges	Research for truck weight legislation. improving communication to legislature for impact of truck weight statute changes	Uncertainty of future technology or direction of autonomous vehicles. Lack of understanding by trucking industry of bridge capacity understanding	Understand proposals, identify what challenges they pose and make changes accordingly	Unclear now what will be needed in terms of resources. Contingent on legislation
10B	Competing Stakeholder Expectations	Not meeting federal condition targets	Using sound asset management approach for funding projects, implementing TAMP	Changing project selection process from worst-first approach to optimized life-cycle strategy. Developing more appropriate targets	Receive adequate funding to fully implement the current mitigation strategy. Base federal targets on an element-level approach	Additional funding
11B	Integration	Inability to manage assets to the lowest life-cycle cost (e.g., preventive activities not performed on a timely basis)	Moving toward a bridge health index to provide better planning scenarios. Improved Life Cycle Planning analysis provides better data behind LCP scenarios. Robust bridge management system. Developing preventive maintenance performance measures	Need to develop performance targets that better allow us to follow a lowest life cycle management decisions	Fully implement using element-level based bridge performance measures and preventive maintenance performance measures	Implementing other risk mitigation strategies would reduce this risk. Use existing staff time, additional funding to implement is needed. Other trade-offs are prioritized that limit our ability to follow lowest LC strategy

Figure B-3: Buildings Asset Risk Register

RISK CODE	RISK CATEGORY	RISK	CURRENT MITIGATION STRATEGY	GAP	IDEAL MITIGATION STRATEGY	RESOURCES NEEDED
1BLDG	Aging Infrastructure	Temporary or permanent building closures	Assessing conditions of buildings as well as engineering studies. Performing PM activities. Investing more into capital projects	Advanced deterioration (brine solution wears away at materials more than salt does). Age causes buildings to become functionally obsolete. Not managing to optimal life cycle management strategy	Develop a plan for data collection and maintenance	Use salt alternative to slow deterioration. Data would help us better understand remaining service life, so we can be more proactive before a building becomes functionally obsolete
2BLDG	Infrastructure Resilience	Efficient building management	Project selection criteria based on several factors to prioritize. Focus on habitable buildings/ those that impact the traveling public.	Missing ADA assessment information which should be included in project selection criteria. Gaps in site and facility functionality - have developed criteria but have not yet implemented. Still need complete site information. Lack of communication and training between functional groups (maint, ops, admin, etc.) which affects our work.	*Rest areas and headquarters:* Include Americans with Disabilities Act assessment information in project selection criteria. ***All buildings:*** Identify communication gaps and find a way to address them	All Buildings: Need better communication. Once program manager is identified, include this as part of the facilities AMP implementation
3BLDG	Data Management/ Lack of Data/ Quality of Data	Lack of data on equipment and components	We have a data management system in place to store data	Do not have install dates of all components. Lack of quality amongst data. Shortcoming on IT support. Lack of staff to enter and maintain data	Develop a plan for data collection and maintenance	Need additional personnel and mobile data collection equipment. Need one-time push to get up to date, then need continuous upkeep of data. Could add this into BIM contract for new buildings (current as built process does not include internal components). Department of Admin includes language - should integrate this into our language as well
4BLDG	Funding	Lack of dedicated capital, operations and maintenance funding	Developed a Facilities Asset Management Plan to communicate funding needs.	Different funding buckets limit our flexibility in how funds are allocated (we used to have flexibility, but this has changed). Staffing varies by districts.	Implement the Facilities Asset Management Plan	Follow the Facilities Asset Management Plan
5BLDG	Competing Stakeholder Expectations	Competing stakeholder expectations	To varying degrees, districts are using building assessments to address most high priority items - better prioritization	Competing with other priorities for funding. Competing between districts for equipment. District spending maintenance money for competing issues (adding to the system rather than maintaining existing system)	Implement the Facilities Asset Management Plan	Follow the Facilities Asset Management Plan
6BLDG	Continuity of Operations	Increasing maintenance equipment and material sizes (e.g., including tow plows, tandems, tanks, brine)	Updating truck stations standards manual. Established fleet liaison to communicate equipment size changes between fleet and buildings	Building may be in good condition, but space does not accommodate larger equipment sizes.	Design based on truck station standards manual	Need to complete the manual. Design teams then need to follow the standards. Frequent discussions with fleet and operation staff about trends in equipment sizes and usages
7BLDG	Response to Disruptive Transportation Technologies	Unforeseen changes in regulatory requirements, travel demands or technology	Working reactively rather than proactively limits our ability to mitigate	Building experts are not always involved in discussions of potential mitigation strategies. Uncertainties with changes with electric vehicles, etc. Executive orders issued and building functional areas notified after the fact. We are reactive rather than proactive	Identify communication gaps and address them	Need better communication. Once program manager is identified, include this as part of the facilities AMP implementation

Figure B-4: Highway Culverts and Deep Stormwater Tunnels Asset Risk Register

RISK CODE	RISK CATEGORY	RISK	CURRENT MITIGATION STRATEGY	GAP	IDEAL MITIGATION STRATEGY	RESOURCES NEEDED
1HCDST	Data Management/ Lack of Data/ Quality of Data	Difficulty in getting inspections done by local agencies on shared tunnel system	MnDOT hired consultants to do inspections	Should be a shared expense, but local agencies often unwilling to provide funding or resources. Then, MnDOT covers the work/ cost	Inspect tunnels according to inspection schedules (local jurisdictions conduct inspections on tunnels with shared water)	Arranging for local agencies to do inspections
2HCDST	Aging Infrastructure	Failure/collapse of culvert due to age or lack of maintenance	Inspection performance measure which is continuously monitored. Annual condition report monitors the risk. Regular communication with district hydraulics engineers	In current investment, culvert system condition is declining each year.Need for continued inspections and increased investments	Rehab culverts before failure occurs and make permanent fixes during future pavement projects	Develop more detailed LCP strategies for different culvert types and features and follow them. Use flow chart for work planning. Consider capacity needs.
3HCDST	Aging Infrastructure	Inability to manage culverts to lowest life cycle cost	During pavement projects, look at poor and very poor conditions rather than only very poor. Standalone culvert rehab projects provide a longer service life and do not impact pavement	Dependent on pavement projects. Deterioration of culverts is complex and is difficult to model. Do not have construction date	Better model and research deterioration. Address culvert needs earlier in pavement project scoping— (e.g., during STIP/CHIP development)	Input more data into TAMS (at a minimum, subset of year built, design data, etc.) to track deterioration over time. Using a subset of typical assets would help inform and may be a good foundation for a research project to analyze deterioration. Better understand additional attributes that contribute to asset deterioration. District hydraulics engineers look at mapped STIP and CHIP projects
4HCDST	Aging Infrastructure	Failure/collapse of tunnel due to age or lack of maintenance	Significant repair of tunnels to get to 0% poor	Need for continued inspections and investments in repairs	Perform regular inspections and invest in recommended repairs (follow ideal LCP strategy)	Local support for those that are maintained by local agencies. Additional funding needed
5HCDST	Data Management/ Lack of Data/ Quality of Data	Lack of statewide location and inspection data for storm drains causes issues with drainage system and affects the roadway	Collected LiDAR data of structure location, which is going into TAMS. Through scoping process, districts are collecting more of the storm drain inventory. Making advances in more affordable technology	LiDAR does not provide pipe data. Funding not allocated. Harder to collect inventory and condition data due to high cost and additional equipment needed	Collect statewide location inventory and inspection data of storm drains	Use existing staff for ongoing needs, hire consultant for up front collection. Video collection, equipment, training, check plans, etc. Better technology in the future may be more cost-effective
6HCDST	Funding	Availability of funds or inconsistency in culvert investments	Districts have detailed scoping process that identifies culverts and includes them in cost estimates	Culverts identified after initial scoping process are difficult to add to project. Funding restrictions limit the number of culvert replacements/ repairs regardless of need	Communicate funding needs (e.g., it's more cost-effective to align culvert replacement with pavement projects; emphasize this approach as an optimization strategy)	Maintain data in TAMS. Ensure project-scoping inspection to catch any needs and update in TAMS
7HCDST	Infrastructure Resilience	Flooding and deterioration due to lack of culvert capacity, resulting in adverse impacts to properties and roadway user safety	Some districts are upsizing or providing storage when culverts are replaced. Check hydraulic capacity of existing culvert when deciding whether to line it	Current scoping processes do not focus on culvert capacity. Some permitting agencies restrict upsizing	Formalize the process of checking hydraulic capacity and the availability of existing culvert storage when deciding whether to line it. Keep track of culverts in areas with flooding problems to determine if they need repair	Run culvert model analysis (ex: hydroCAD for storage). Use flood vulnerability tool, historical flood data, and TAMS work orders. Consult with maintenance to identify areas that have flooding issues. Both: develop database to track this data
8HCDST	Infrastructure Resilience	Flooding and deterioration due to a lack of tunnel capacity, resulting in adverse impacts to property and roadway user safety	Provided cost estimates for increasing capacity. Installed a stormwater storage facility	Tunnels are tied into other systems owned by other jurisdictions, so we have limited control over other systems	Add recommended tunnel capacity	Funding and support from local cities, MnDOT owns tunnels, but local agencies have a greater share of water within our tunnel systems - local agencies help maintain those with shared water.Understand capacity needs for some tunnels, but not all
9HCDST	Infrastructure Resilience	Significant damage to culverts through human-caused events	Full inventory of locations. Work with other stakeholders to provide maps of drainage infrastructure for those working on ROW or adjacent developments	Highway culverts have a least one side located statewide, but do not have elevations or location of both pipe ends for all culverts	Complete location inventory, continue current inspections and identify damage and repair needs	Work with other utilities and permits to make sure our assets are known (partially implemented but need to expand statewide). Ensure this data is included in MnDOT project plans. Place physical markers on culverts so others know they are there

Figure B-5: Intelligent Transportation Systems Asset Risk Register

RISK CODE	RISK CATEGORY	RISK	CURRENT MITIGATION STRATEGY	GAP	IDEAL MITIGATION STRATEGY	RESOURCES NEEDED
1ITS	Funding	Inconsistent operations/ maintenance, funding for staff, equipment and construction	We have used one-time funds to purchase equipment	Not sustainable and does not meet all needs. Unreliability limits our ability to plan and implement	Communicate funding needs. Develop and track uptime performance measures	IRIS provides communication data to show which assets are functional. Feed that data into DJANGO to identify work needs (not available for all devices - additional tools may be needed. Research best practices on this topic). TAMS may be an alternative for tracking work order completions
2ITS	Infrastructure Resilience	Standardization in system design, construction issues or system flaws	Update standards in design manual	Unable to conduct face-to-face training due to COVID restrictions	Update standards in design manual and provide training on standards. Create a construction manual, provide certification training	Continuous effort needed in the long term to keep the manuals up-to-date and provide training. Include contractors in training
3ITS	Succession Planning	Staff turnover and lack of documentation	Changes are documented and added to SharePoint to keep others informed (knowledge books, continuity manuals)	Want to better document procedures and what these systems are. Cannot have staffing overlap with cross-training before staff leaves	Update standards in the design manual and provide training on standards. Create a construction manual, provide certification training. Create an operations and maintenance manual, provide training	Continuous effort needed in the long term to keep the manuals up-to-date and provide training. Include contractors in training
4ITS	Integration	Not identifying an appropriate responsible party for maintenance/ operations	None	Identified that this is a risk that requires mitigation and are in initial discussions but have not fully addressed yet.	Develop workflows	Committee to determine what the responsibilities are
5ITS	Continuity of Operations	Issues with vendor skills, ability and availability to provide support	Tightened specifications, awarded multiple contracts	Dependent on health of the company.	Add more details into RFPs to ensure support and reliability of potential vendors for selection	Internal staff
6ITS	Response to Disruptive Transportation Technologies	Technology shift/ obsolescence	Use technology independent equipment, multi-year contracts, approved products list, use experimental products in small test cases	Inability to replace technology when vendor no longer manufactures or supports equipment due to lack of staffing and resources. Inadequate replacement cycles to keep up to changing technologies	Create plans to address potential obsolescence	Data tracking, research upcoming trends
7ITS	Response to Disruptive Transportation Technologies	Supply availability, equipment shortages and shipping disruptions	Stocking up on products - MnDOT purchases equipment in advance of contracts and furnishes it to vendors (applies to some projects)	Don't have a large enough stock of products (can be an issue if we stock too much of old equipment). Underutilized warranties. Have to meet certain criteria	Standardize certain materials rather than customizing based on location	Staff time, and potentially additional consultant time

Figure B-6: Noise Walls Asset Risk Register

RISK CODE	RISK CATEGORY	RISK	CURRENT MITIGATION STRATEGY	GAP	IDEAL MITIGATION STRATEGY	RESOURCES NEEDED
1NW	Data Management	Not keeping asset inventory and condition data current and consistent in TAMS	As-builts are a contract pay item that provides survey data with high accuracy. If as-built data is not provided, then MnDOT staff provide field data collection	We are transitioning to a new rating system, which may cause confusion in what condition data is reported. Limited ways to get data into TAMS. Changes in TAMS are not more widely distributed to other systems	Annually collect asset inventory and condition data using LiDAR. Maintain a regular inspection schedule to collect data that LiDAR cannot capture. Inspect noise walls at appropriate frequencies to promptly address fixes	Develop more flexibility in making adjustments in TAMS. Need additional staff for inspections and data processing. LiDAR would not have all the data we would need, so we would need staff to fill in the gaps. Inspections would still be needed because of limitations with what LiDAR can collect
2NW	Funding	Noise walls may lack prioritization in funding allocation decisions	In metro, we are using a portion of standalone maintenance program setaside towards noise wall maintenance using a consent agreement	We developed a substantially complete risk rating per wall, but not yet used in prioritization. no standard funding for roadside infrastructure maintenance	Consider noise walls earlier in scoping process to include them in project costs	Use Noise Wall's risk tool to understand and prioritize needs - the tool needs additional work to finalize it. Education to project managers to check wall condition as part of projects
3NW	Aging Infrastructure	Not managing noise walls to optimize the life cycle management strategy	Recommended new installations to be concrete which require lowest life cycle cost strategy	Maintenance activities are more reactive than proactive	Set up work plans for walls based on their age and condition	Implement TAMS planning tool. Need inventory and condition data to inform the work plan. Consultant contracts to conduct preventive maintenance (MnDOT staff would continue to address reactive maintenance)
4NW	Integration	Inconsistent application of existing data for capital and preventive maintenance decision making	Capital found ways to use existing data to program repair projects as funding becomes available. Noise Walls condition scoping worksheet to use in project scoping	Do not have the same mitigation strategies for maintenance. Maintenance work is primarily reactive, rather than proactive using TAMS data	Set cyclical repair either as part of the inspection process or from TAMS recommendations	Educate project managers on availability of data
5NW	Competing Stakeholder Expectations	Poor aesthetics of noise walls are a visual issue for neighbors, whereas structural condition is MnDOT's priority	For paint issue: developed a performance-based paint spec for wood noise walls using a specialist. MnDOT's Highway Sponsorship program: other entities can be involved in funding aesthetics	Trade-off of choosing local partnership (aesthetic-focused) over structural issues. Unable to evaluate this. Complaint-driven prioritization. Issues with previous paint types. finding a solution to repainting	Fund aesthetics based on performance-based paint specifications (alternatively, MnDOT will prioritize additional funding through other means unless there is dedicated aesthetic funding)	Potentially use the highway sponsorship program for additional public/private partnerships to seek funding from others for aesthetics

Figure B-7: Overhead Signs Asset Risk Register, 1 of 2

RISK CODE	RISK CATEGORY	RISK	CURRENT MITIGATION STRATEGY	GAP	IDEAL MITIGATION STRATEGY	RESOURCES NEEDED
1OS	Aging Infrastructure	Premature deterioration of the asset (e.g., salt corrosion, loose nuts)	Inspections, nut tightening	Not enough inspection. Research needed to better understand factors that result in premature deterioration. lack of funding to tighten nuts results in foundation replacement	Inspect every five years using a standard inspection form to identify overhead signs that may require more frequent inspections. Revise standards (e.g., MnDOT previously used grout but found it led to premature deterioration)	Use inspections to develop work plan that prioritizes assets with more severe deterioration. For those with recurring or more severe issues, recommend a more frequent inspection cycle. Note: most districts do inspections. One does "some", but all do not have dedicated resources for inspection. Identify elements with issues across entire inventory. Use consistency with entering inspection data - Use signs committee to communicate need of consistency
2OS	Infrastructure Resilience	Structure design is inadequate for increasing panel sizes	Ask for data from supplier	Look at monotube structures proactively. missing data such as structure measurements. (Panel sizes may increase due to increase in text or changes in requirements of text sizes, etc.)	Identify when sign panel sizes are outside of standards. Verify with engineer the use of current design specifications in standard plans	Track requests and responses (may use metro's process of tracking in ProjectWise).

Figure B-7: Overhead Signs Asset Risk Register, 2 of 2

RISK CODE	RISK CATEGORY	RISK	CURRENT MITIGATION STRATEGY	GAP	IDEAL MITIGATION STRATEGY	RESOURCES NEEDED
3OS	Integration or Infrastructure Resilience	Poor construction and/or installation (e.g., post tilt and loose nuts)	Training of new specification. new installation practices with checklist and documentation. Various related research	Foundation issues	Train installers and certify inspectors. Ensure construction inspections are done correctly and any construction flaws are fixed	Develop handbook. Develop MnDOT inspection certification program. Use TAMS during construction to capture initial asset inspection data, noting any installation issues. Communicate problems so installers can address installation flaws
4OS	Infrastructure Resilience	Significant damage to asset or structural failure due to natural events	Rapid response to incidents with engineering analysis. Built to standard	Don't have documentation on response process	Develop a new response process and ensure it is understood by all parties. (Continue to focus on response due to an inability to predict these events)	Use new design types with more redundancy. Ensure certified staff are responding to hits
5OS	Succession Planning or Continuity of Operations	Shortage of workforce, retirements and documentation	Create documentation and staffing responsibilities	Ability of concurrent training, ability to staff at appropriate position classification	Train and hire staffing concurrently. Fostering consistent documentation standards across districts	Generate a knowledge book (like what bridge is doing). Use signs committee to communicate need of consistency. Need a replacement planning strategy. May use pro-plan to aid in knowledge transfer
6OS	Response to Disruptive Transportation Technologies	Unforeseen changes in regulatory requirements, travel demands or technology	Proactive to understanding which changes are needed and build in enough time to adapt to changes - update policies and standards accordingly. Develop standards to adapt	lack of expertise in understanding uncertainties	Pilot new technology with experimental projects before widespread implementation	Use existing staff along with potential consultant contract to conduct pilots

Figure B-8: Pedestrian Infrastructure Asset Risk Register, 1 of 2

RISK CODE	RISK CATEGORY	RISK	CURRENT MITIGATION STRATEGY	GAP	IDEAL MITIGATION STRATEGY	RESOURCES NEEDED
1PED	Data Management/ Lack of Data/ Quality of Data	Current approach to collecting inventory and condition data is labor intensive and the data cycle is 10 years	Building the inventory and condition is the mitigation strategy. Current data collection approach is labor intensive and the data cycle is currently ten years.	Incomplete baseline inventory. (This should support a data driven decision making process.) Lack of functional data tools (web maps, spatial, etc.) to help scoping and implementation	Collect pedestrian assets using mobile LiDAR	Build capacity with post processing data collected from mobile lidar (asset grade accuracy)
2PED	Aging Infrastructure	Not meeting federal ADA compliance or its intent	The maintenance throughout the lifecycle is minimal, compliant driven. No oversight of community contracts	The maintenance throughout the lifecycle is minimal, compliant driven. No oversight of community contracts	Develop and pilot performance measures for maintaining pedestrian facilities in partnership with local jurisdictions. Identify consistent maintenance approaches to better define responsibilities included in maintenance agreements under cooperative agreements and in master maintenance agreements	Full implementation of TAMS and external partner/consultant documentation. The Master Maintenance Agreement efforts are moving slowly. There are 4 pilot counties working on this with MnDOT, being facilitated by a consultant. That contract is about $100,000 and there may not be even one MMA in place at the end of that contract. It will take years to fully implement and will be at least a couple million dollars
3PED	Aging Infrastructure	Difficulty following a life cycle management strategy	Using the TAMP to help inform lifecycle planning scenarios	limited funding, limited ability to move away from a reactive management strategy due to existing business process, uncoordinated, and limited baseline inventory and condition data. Needs district advocates to help implement strategies	Fully integrate assets into TAMS work order process. Develop MnDOT guidance on best practices for maintenance of pedestrian assets	Staff adhere to MnDOT standards and ADA tech memo for design and construction. And develop best practices for maintenance
4PED	Succession Planning	Staff turnover limits the ADA program's ability to address liability, essential services and ADA planning at the district and project level	ADA Transition Plan and conversations with Operation Division Leadership	There is no succession planning for staff within the ADA unit. There is also no ADA staff at the district level to provide redundancy and accountability	Increase capacity among existing staff and hire additional staff at the district level	Training current staff on everything ADA

Figure B-8: Pedestrian Infrastructure Asset Risk Register, 1 of 2

RISK CODE	RISK CATEGORY	RISK	CURRENT MITIGATION STRATEGY	GAP	IDEAL MITIGATION STRATEGY	RESOURCES NEEDED
5PED	Infrastructure Resilience	Poor planning, design and/or construction	Construction inspection, ADA compliance, field walks, plan reviews, sidewalk evaluation	Lack of funding and staff to fully implement existing strategies and to comply with Complete Streets policy and Ped Plan	Continue current control and mitigation strategies. Incorporate 3D modeling to improve planning, design and construction	Work with Todd Berglin's group to ensure that one of the district's pilot projects include pedestrian assets in the 3D modeling. Complete the baseline for the inspection data to become the data of record...incorporate into the TAMS ultimately (TAMs Work Manager--includes work orders, inspection frequency)
6PED	Continuity of Operations	Not receiving local consent/agreement resulting in a lack of operations/ maintenance and oversight that leads to premature deterioration	Developing master maintenance agreements with counties.	Inconsistent oversight and enforcement of agreements. If issues come up, MnDOT is responsible. County master maintenance agreements do not fully mitigate this risk	Implement the master maintenance agreements	Full implementation of TAMS and external partner/consultant documentation. The Master Maintenance Agreement efforts are moving slowly. There are 4 pilot counties working on this with MnDOT, being facilitated by a consultant. That contract is about $100,000 and there may not be even one MMA in place at the end of that contract. It will take years to fully implement and will be at least a couple million dollars
7PED	Competing Stakeholder Expectations	Not meeting the needs of system users	Addressing user complaints with existing plans and maintenance requests within a reasonable timeframe	Taking a reactive compliant driven approach. Underutilizing the TAMS infrastructure to accommodate maintenance requests.	Develop performance measures based on location, type of repair and response timeframe to address complaints. Identify trends to support a more proactive approach	Full implementation of TAMs

Figure B-9: Traffic Signals, Lighting and High-Mast Light Towers Asset Risk Register, 1 of 2

RISK CODE	RISK CATEGORY	RISK	CURRENT MITIGATION STRATEGY	GAP	IDEAL MITIGATION STRATEGY	RESOURCES NEEDED
1SLHMT	Aging Infrastructure	Not managing assets appropriately resulting in poor asset condition, which impacts the safety of the traveling public	Developing a more formal/ standardized structural inspection. Utilizing TAMS to program. Signals and lighting considered when scoping pavement projects	Not able to perform regular structural inspection and PM due to lack of staffing and funding. Life cycle replacement program not in place for standalone projects. Often times, local agencies do not contribute their share of funding for replacements	Ensure adequate staffing for structural inspection throughout asset life cycle. Develop life cycle replacement or preservation program for standalone projects	Group component replacements and/or upgrades - we often have one-time funding where we do a lot at once, which means they will become due all at once and no dedicated funding to address. Document programs and needs for if/when there is staff turnover. Finish gathering condition data
2SLHMT	Funding	Lack of consistent dedicated funding/ staffing limits the ability to effectively manage and operate existing assets	Contract out some work using district SRC funds. Identified staffing gaps, one-time funding need to address gaps, and annual funding need. MnSHIP looks specifically at signals/lighting and performance levels based on various funding scenarios. Use TAMS to develop funding needs	Have not received money that the program has identified as a need. Also, have not received necessary staffing levels. Lighting receives leftover funding at the end of the year, but not the case for signals	Document and communicate needs (e.g., business plans)	Identify gaps to come up with need
3SLHMT	Infrastructure Resilience	Premature deterioration due to extreme weather or environmental factors	Do PM inspections. Specification changes - now using galvanized signal poles. Also, using better quality lighting poles. In Process: Using AASHTO standards. Working with manufacturers on issues with new poles. Working on design changes for materials that are more resilient	Many signal poles are not galvanized - limited ability to replace due to financial constraints	Continue to follow through and fully implement "in-process" mitigation strategies	Need support from manufacturers on requested changes. Enhance installation checklist to include new standards. Ensure that issues are being reported. Have staff do regular PM checks, including training and applying PM activities

Figure B-9: Traffic Signals, Lighting and High-Mast Light Towers Asset Risk Register, 2 of 2

RISK CODE	RISK CATEGORY	RISK	CURRENT MITIGATION STRATEGY	GAP	IDEAL MITIGATION STRATEGY	RESOURCES NEEDED
4SLHMT	Infrastructure Resilience	Damage due to hits by traveling public	Added requirements for location placements	Inability to predict hits, as they may be due to drivers under the influence, unpredictable crashes, etc.	Increase resources to respond to incidents more quickly (there are several options for prevention, but none that are based on competing factors)	Dedicated lighting crew in metro. Additional trained personnel and equipment (pole setter, lane control, etc.)
5SLHMT	Response to Disruptive Transportation Technologies	Cybersecurity breaches or hardware/software incompatibility and upgrades	Firmware upgrades tracked in share point site. Network management (firewalls, device configurations, segmentation, etc.). Updated laptops and devices to be able to program devices remotely and view with cameras to make sure they are functioning	Currently, anyone can purchase a cabinet key and manipulate the system. Mostly affects signals. Obsolescence is an issue - no longer supported by manufacturer requires a replacement. Firmware upgrades. Lack of funding and personnel to upgrade the system. No procedure or policy identifying responsibility. Lack of communication between IT and functional area (ex: IT shut down servers without notification)	Use more secure passwords (Cybersecurity mitigation provided through MNIT). Add locks to cabinets, mostly done through vendors	Create a system for tracking passwords
6SLHMT	Infrastructure Resilience	Poor construction, installation, design specifications or fabrication	Require contractors to be certified (MnDOT's signal and lighting certification). Specification changes and product improvements (nut tightening, galvanizing, etc.). Construction spec checklist. Workmanship warranties. Inspectors specialize in signals and lighting	We have a gap of dedicated staff to get out to sites for inspection	Need dedicated statewide construction inspectors trained in signals and lighting (e.g., electrical components)	Need additional dedicated inspection staff - minimum 2-4 for greater MN (have 4 in metro already)
7SLHMT	Continuity of Operations	Power outages result in a non-operational system	Some signals have battery backup (but very small amount - prioritized by critical locations and does not provide enough benefit to do this system-wide). Some tunnels have dual power feed. Place stop signs at locations where outage will likely not be quickly repaired	Need to modernize tunnel lighting (LED) to provide backup power system	Modernize tunnel lighting by providing backup power systems (focus on tunnels due to more critical safety risks). Communicate to the traveling public when systems are out of operation	Modernize: install a backup power system.Communication: notifications on DMS, radio stations, news outlets, 511, navigational map applications, etc. (some being done already). Public education on what it means when a signal is out. Technicians available on-call to quickly respond
8SLHMT	Multimodal Safety	Signal inoperability results in decreased safety benefits to the traveling public and negative perceptions of how MnDOT manages assets	Signals that go into flash. Different types of PM for signals. Replacing outdated electronics (MMUs). Spec and design changes (connectors, etc.). Those connected to central system allow us to identify outages and respond more quickly. Determining if signals are still required and sometimes replacing with roundabouts or alternative stop control. There is a 24/7 call system for the public to report outages, which minimizes downtime	Few signals are not connected to central system. Limited resources to do more evaluations of whether systems are still warranted. Local agencies are responsible for some maintenance activities - often they are not responsive, and we keep systems operational on their behalf	Continue to upgrade equipment to the central system. Follow life cycle management strategy on all equipment to minimize failures	Include ideal life cycle planning strategy in business plans. Make sure to define strategies for components of the system. Make agreement with manufacturers on service life. Upgrade Maxview (central system)
9SLHMT	Multimodal Safety	Lighting inoperability results in decreased safety benefits to the traveling public and negative perceptions of how MnDOT manages assets	Replacing with LED bulbs (most of the system has been replaced). There is a 24/7 call system for the public to report outages, which minimizes downtime (Webpage lists contacts for reporting as well)	No traffic management cameras to view device status. No regular PM program due to lack of funding. No fiber optic communication between device and software system	Follow life cycle management strategy on all equipment to minimize failures	Include ideal life cycle planning strategy in business plans. Make sure to define strategies for components of the system. Make agreement with manufacturers on service life
10SLHMT	Response to Disruptive Transportation Technologies	Poor traffic signal timing results in increased user delay and crashes	Developed a signal timing shared service	Need funding to implement signal timing shared service. Competing district work priorities result in signal timing not being addressed	Implement signal timing performance measure (e.g., retime on-demand as needed)	It will be much easier when we upgrade our central system, as we will have the necessary tools to implement. Additional staff time or consultant time needed

APPENDIX C - LIFE CYCLE PLANNING

LIFE CYCLE PLANNING APPROACH FOR ANCILLARY ASSETS

For each asset included in the TAMP except pavement, bridge and buildings, the following information was compiled to facilitate the LCP analysis:

- **Asset inventory and condition**. The information on the size of the asset network and the distribution of assets in each condition category (e.g., good, fair, poor, etc.) was based on a combination of information available from asset inspection records and estimates provided by asset managers.
- **Network growth rate.** An estimate of how the asset inventory size changes from year to year was determined based on historical data and input from the districts.
- **Condition deterioration models.** The amount of time an asset takes to deteriorate from one condition state to another was modeled based on the expert judgment from the asset managers.
- **Treatment actions.** The type of treatment actions applied to the asset based on its condition state and the average unit cost associated with each treatment action was established based on current asset management practices.
- **Treatment impact matrix.** A treatment impact matrix was established to determine how the asset condition changes after a treatment is applied.
- **Treatment strategies.** Three treatment strategies were evaluated for each asset:
    - **Minimum Maintenance.** Impact of just applying routine maintenance treatments and not investing in any preservation or rehabilitation activities.
    - **Current Strategy.** Impact of following MnDOT's current approach to managing assets.
    - **Desired Strategy.** The adjustment needed to MnDOT's current treatment strategies to achieve the desired performance target in 10 years.

Additional details are provided in the following sections.

ASSET CONDITION STATES

Assets are classified into 2, 3, or 4 condition states, depending on the asset type. Details on the inventory and condition ratings utilized for each asset are available in **Chapter 3, Asset Inventory, Condition and Valuatio**n. Figure C-1 summarizes the number of condition states and the condition categories for each asset.

Figure C-1: Asset Condition States and Categories

ASSET	NUMBER OF CONDITION STATES	CONDITION CATEGORIES
Highway Culverts	4	Good, Fair, Poor, Very Poor
Deep Storm water tunnels	4	Minor/ Moderate, Moderate, Significant, Very Significant
Overhead sign structures	3	Good, Fair, Poor
High-Mast Tower Light Structures	4	Good, Fair, Poor, Beyond Useful Life
Noise Walls (Concrete and Wood)	4	Good, Fair, Poor, Very Poor
Traffic Signals	4	Good, Fair, Poor, Beyond Useful Life
Lighting	4	Good, Fair, Poor, Beyond Useful Life
Pedestrian Infrastructure	2	Compliant, Non-Compliant
Intelligent Transportation Systems	3 or 4 depending on sub asset*	Good, Fair, Poor, Very Poor (Critical) (4) Good, Fair, Poor (3)

ANALYSIS PERIOD AND NETWORK GROWTH RATE

- Long enough that future costs (beyond the chosen analysis period) do not impact the results significantly.
- Long enough that at least one complete asset replacement cycle is included.

Expert judgment (from asset managers) and the expected impact of treatments on the asset life were used to finalize the analysis periods adopted for each asset. The network growth rate was determined based on historical data and expert judgment. Figure C-2 summarizes the analysis period and network growth rate for each asset.

Figure C-2: Analysis Period and Network Growth Rate of Assets

ASSET	NUMBER OF CONDITION STATES	CONDITION CATEGORIES
Highway Culverts	100	0
Deep Storm water tunnels	100	0
Overhead sign structures	50	10
High-Mast Tower Light Structures	50	3
Noise Walls (Concrete and Wood)	100	2 (Wood) 8 (Concrete)
Traffic Signals	50	0
Lighting	50	5
Pedestrian Infrastructure: Curb Ramps and Sidewalk	20 (Curb Ramps) and 30 (Sidewalk)	3
Intelligent Transportation Systems	50	Varies by ITS asset type

CONDITION DETERIORATION MODELS

A Markov process was used to model asset condition deterioration, and a condition transition probability matrix was established for each asset. These matrices describe the time taken to deteriorate from one condition state to another (e.g., good to fair or fair to poor).

An example of a Markov transition probability matrix is shown in Figure C-3. In this example, assets can deteriorate from good to fair and fair to poor. Assets cannot deteriorate from good to poor without being in the fair state at some point in time. If we assume that 100% of the asset network is in good condition today and it takes 20 years for 50% of the network to deteriorate to a fair condition and 10 years for 50% of the assets in fair condition to deterioration to a poor condition, the condition transition probability is based on the following rules:

- 3.4% of the asset network will deteriorate from a good to fair condition every year.
- 6.7% of the asset network will deteriorate from a fair to poor condition every year.

Figure C-3: Illustration of Markov Transition Probability Matrix

TRANSITION STATES	YEARS	GOOD	FAIR	POOR
Good to Fair	20	96.6%	3.4%	N/A
Fair to Poor	10	N/A	93.3%	6.7%

TREATMENT STRATEGIES

The annual treatment distributions define the percentage of the network in a particular condition state that will receive the treatments identified in each year over the chosen analysis period. Figure C-4 illustrates annual maintenance fractions associated with a treatment strategy.

Figure C-4: Illustration of Annual Treatment Distributions

TREATMENT	% ANNUALLY TREATED IN GOOD CONDITION	% ANNUALLY TREATED IN FAIR CONDITION	% ANNUALLY TREATED IN POOR CONDITION	UNIT COST ($/ ASSET
Reactive Maintenance	1%	2%	3%	$90,000
Inspection	20%	20%	20%	$200
Major rehab	0%	0%	5%	$19,000
Replacement	0%	0%	3%	$125,000

In the example shown in Figure C-4, 1% of the assets in good condition, 2% of the assets in fair condition, and 3% of the assets in poor condition receive reactive maintenance each year. Different treatment strategies are generated by changing the annual maintenance fractions associated with each treatment action.

Figure C-4 also shows the example unit costs for each treatment. Treatment unit costs help determine the estimated spending level for the analysis year based on the fraction of assets in each condition category and the applicable maintenance actions associated with the treatment strategy chosen.

TREATMENT IMPACT MATRIX

A treatment impact matrix is used to determine the impact of a treatment application on the condition of the asset. An example impact matrix is shown in Figure C-5.

Figure C-5: Illustration of Impact Matrix

(Treatments and Resulting Asset Condition after Treatment Application)

CURRENT CONDITION	REACTIVE MAINTENANCE	INSPECTION	MAJOR REHAB	REPLACEMENT
Good	Good	Good	N/A	N/A
Fair	Fair	Fair	N/A	N/A
Poor	Poor	Poor	75% to Good and 25% to Fair	Good

Treatment application can have several different impacts on the resulting asset condition, as summarized below (and illustrated in Figure C-5):

- **No Impact on Condition:** The application of certain treatments (such as reactive maintenance and inspection) has no impact on the resulting condition.
- **Improve to Higher Condition Category:** Certain treatments improve the condition category by one or more condition states. For example, replacing an asset in poor condition changes the resulting condition to good.
- **Fractional Condition Improvement:** Some treatments have fractional improvements on the asset condition. For example, applying a major rehabilitation treatment to assets in poor condition results in shifting 75% of the assets in poor condition to a good condition category. The remaining 25% of the assets are improved to a fair condition category.

LIFE CYCLE PLANNING INPUTS AND ASSUMPTIONS FOR ANCILLARY ASSETS

The analysis inputs and assumptions used for each assets other than pavements, bridges and buildings are documented below.

HIGHWAY CULVERTS

To compare highway culverts to other assets in the TAMP, staff combined the poor and very poor condition rating into a category called poor.

Figure C-6 presents the deterioration models for each LCP approach evaluated. An explanation of the Markov transition matrix and deterioration from one condition state to another is in Figure C-3.

Figure C-6: Deterioration Models for Highway Culverts

APPROACH	TRANSITION STATES	YEARS	GOOD	FAIR	POOR	VERY POOR
Current	Good to Fair	10	93.3%	6.7%	N/A	N/A
Current	Fair to Poor	14	N/A	95.2%	4.8%	N/A
Current	Poor to Very Poor	6	N/A	N/A	89.1%	10.9%
Desired	Good to Fair	10	93.3%	6.7%	N/A	N/A
Desired	Fair to Poor	16	N/A	95.8%	4.2%	N/A
Desired	Poor to Very Poor	8	N/A	N/A	91.7%	8.3%

Figure C-7 and C-8 present the unit costs and annual treatment distributions for the current and desired approaches, respectively.

Figure C-7: Annual Treatment Distributions for Highway Culverts - Current Approach

TREATMENT	% ANNUALLY TREATED IN GOOD CONDITION	% ANNUALLY TREATED IN FAIR CONDITION	% ANNUALLY TREATED IN POOR CONDITION	% ANNUALLY TREATED IN VERY POOR CONDITION	UNIT COST ($ PER ASSET)
Inspection	17%	17%	30%	60%	$100
Cleaning	0.5%	0.5%	2.5%	4%	$1,000
Reset ends	0%	0%	1%	0.5%	$3,900
Joint repair	0%	0%	0.5%	0.5%	$3,440
Pave invert	0%	0%	0.1%	0%	$1,840
Replace ends	0%	0%	0.5%	0.2%	$5,630
Slipliner	0%	0%	0.5%	0.3%	$14,000
CIPP	0%	0%	3%	9%	$19,500
Replace-Trench	0%	0%	1.7%	6.9%	$31,500
Replace -Jack	0%	0%	0%	0.5%	$91,000

Figure C-9 shows the treatment impact matrix for highway culverts. It reflects the change in conditions expected after each treatment has been applied. Key assumptions are listed below:.

- Inspection and cleaning have no impact on condition.
- Reset ends, joint repairs, pave invert and replace ends improves asset condition by one condition state (fair to poor, poor to fair, and very poor to poor).
- Slipliner and CIPP, when applied to assets in in poor and very poor conditions, improve 90% to fair condition and 10% to good condition.
- Replace-trench and replace-jack restores assets in poor or very poor condition to good condition.

Figure C-8: Annual Treatment Distributions for Highway Culverts - Desired Approach

TREATMENT	% ANNUALLY TREATED IN GOOD CONDITION	% ANNUALLY TREATED IN FAIR CONDITION	% ANNUALLY TREATED IN POOR CONDITION	% ANNUALLY TREATED IN VERY POOR CONDITION	UNIT COST ($ PER ASSET)
Inspection	17%	17%	30%	60%	$100
Cleaning	0.5%	0.5%	2.5%	4%	$1,000
Reset ends	0%	0%	3%	1%	$3,900
Joint repair	0%	0%	5%	1%	$3,440
Pave invert	0%	0%	1%	0%	$1,840
Replace ends	0%	0%	3%	1%	$5,630
Slipliner	0%	0%	1%	1%	$14,000
CIPP	0%	0%	7.2%	10%	$19,500
Replace-Trench	0%	0%	4%	11%	$41,000
Replace -Jack	0%	0%	0%	1%	$91,000

Figure C-9: Treatment Impact Matrix for Highway Culverts

(Treatments and Resulting Asset Condition after Treatment Application)

CURRENT CONDITION	INSPECTION	CLEANING	RESET ENDS	JOINT REPAIR	PAVE INVERT	REPLACE ENDS	SLIPLINER	CIPP	REPLACE TRENCH	REPLACE JACK
Good	Good	Good	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Fair	Fair	Fair	Good	Good	Good	Good	N/A	N/A	N/A	N/A
Poor	Poor	Poor	Fair	Fair	Fair	Fair	Good (10%)/ Fair (90%)	Good (10%)/ Fair (90%)	Good	Good
Very Poor	Very Poor	Very Poor	Poor	Poor	Poor	Poor	Good (10%)/ Fair (90%)	Good (10%)/ Fair (90%)	Good	Good

DEEP STORMWATER TUNNELS

The Deep Stormwater Tunnels rating system does not use good/fair/poor terminology. In order to compare tunnels to other assets in the TAMP, staff translated the tunnel rating as follows:

- Minor to Moderate Defects = good
- Moderate Defects = fair
- Significant to Most Significant Defects = poor

Figure C-10 presents the deterioration models used for each LCP approach evaluated. An explanation of the Markov transition matrix and deterioration from one condition state to another is in Figure C-3.

Figure C-10: Deterioration Models for Deep Stormwater Tunnels

APPROACH	TRANSITION STATES	YEARS	MINOR TO MODERATE	MODERATE	SIGNIFICANT	MOST SIGNIFICANT
Current	Minor/Moderate to Moderate	14	95.2%	4.8%	N/A	N/A
Current	Moderate to Significant	32	N/A	97.9%	2.1%	N/A
Current	Significant to Very Significant	14	N/A	N/A	95.2%	4.8%
Desired	Minor/Moderate to Moderate	14	95.2%	4.8%	N/A	N/A
Desired	Moderate to Significant	32	N/A	97.9%	2.1%	N/A
Desired	Significant to Very Significant	14	N/A	N/A	95.2%	4.8%

Figures C-11 and C-12 present the unit costs and annual treatment distributions for the current and desired approaches, respectively.

Figure C-11: Annual Treatment Distributions for Deep Stormwater Tunnels - Current Approach

TREATMENT	% ANNUALLY TREATED IN MINOR TO MODERATE DEFECTS	% ANNUALLY TREATED IN MODERATE DEFECTS	% ANNUALLY TREATED IN IN SIGNIFICANT DEFECT	% ANNUALLY TREATED IN MOST SIGNIFICANT DEFECT	UNIT COST ($ PER ASSET)
Inspection	10%	25%	1%	1%	$14
Routine Maintenance	1%	1%	1%	1%	$30
Repairs (Fill voids behind tunnels, seal cracks)	0%	1%	50%	100%	$700
Minor Rehab (Steel band installation)	0%	0%	0%	0.5%	$1,600
Major Rehab (Replacement)	0%	0%	0%	0.5%	$7,000

Figure C-12: Annual Treatment Distributions for Deep Stormwater Tunnels - Desired Approach

TREATMENT	% ANNUALLY TREATED IN MINOR TO MODERATE DEFECTS	% ANNUALLY TREATED IN MODERATE DEFECTS	% ANNUALLY TREATED IN SIGNIFICANT DEFECT	% ANNUALLY TREATED IN MOST SIGNIFICANT DEFECT	UNIT COST ($ PER ASSET)
Inspection	10%	25%	10%	10%	$14
Routine Maintenance	2%	2%	2%	2%	$30
Repairs (Fill voids behind tunnels, seal cracks)	0%	1%	75%	100%	$700
Minor Rehab (Steel band installation)	0%	0%	0%	1%	$1,600
Major Rehab (Replacement)	0%	0%	0%	1%	$7,000

Figure C-13 shows the treatment impact matrix for deep stormwater tunnels. It reflects the change in conditions expected after each treatment has been applied. Key assumptions are listed below:

- Inspection and routine maintenance have no impact on condition.
- Repairs (fill voids behind tunnels, seal cracks), minor rehab (steel band installation), and major rehab (replacement) restore assets to a Minor to Moderate Defects (good) condition state.

Figure C-13: Treatment Impact Matrix for Deep Stormwater Tunnels (Treatments and Resulting Asset Condition after Treatment Application)

CURRENT CONDITION	INSPECTION	ROUTINE MAINTENANCE	REPAIRS	MINOR REHAB	MAJOR REHAB
Minor to Moderate Defects (Good)	Minor to Moderate Defects	Minor to Moderate Defects	N/A	N/A	N/A
Moderate Defects (Fair)	Moderate Defects	Moderate Defects	N/A	N/A	N/A
Significant Defects (Poor)	Significant Defects	Significant Defects	Minor to Moderate Defects	Minor to Moderate Defects	Minor to Moderate Defects
Most Significant Defects (Poor)	Most Significant Defects	Most Significant Defects	Minor to Moderate Defects	Minor to Moderate Defects	Minor to Moderate Defects

INTELLIGENT TRANSPORTATION SYSTEMS

Figure C-14 summarizes the deterioration models for each ITS asset.

Figure C-14: Deterioration Models for ITS Assets

(Years to Deteriorate from One Condition State to Another)

Note: Assumed probability of deteriorating from one condition state to another = 90%

ITS ASSET	GOOD TO FAIR	FAIR TO POOR	POOR TO BEYOND USEFUL SERVICE LIFE
Fiber Communication Network Miles	15	5	5
Fiber Network Shelters	10 (Current Approach) 15 (Desired Approach)	5	5
Traffic Management System Cabinet	8 (Current Approach) 10 (Desired Approach)	8 (Current Approach) 6 (Desired Approach)	5
Dynamic Message Signs	9	4	2
Traffic Monitoring Cameras	5	4	3
Traffic Detector Stations/Site-Loops/Radar	15 Functional to Non-Functional	-	-
E-ZPass Readers	10	3	2
Reversible Road Gates	9	4	4
Ramp Meters	25	25	-
Road Weather Information Systems Sites	20	15	5
Automatic Traffic Recorders Sensors	6	3	3
Weigh-In-Motion System Sites Senors	6	3	3

Figure C-15 presents the average unit costs for each treatment category for ITS assets.

Figure C-15: Unit Cost by Treatment Category for ITS Assets (Unit Cost)

ITS ASSET	ROUTINE MAINTENANCE	PREVENTIVE MAINTENANCE	MINOR REHAB	MAJOR REHAB	REPLACEMENT
Fiber Communication Network Miles	$0	$0	$15,000	$15,000	$90,000
Fiber Network Shelters	$0	$250	$700	$2,500	$110,000
Traffic Management System Cabinet	$150	$0	$350	$600	$14,000
Dynamic Message Signs	$250	$250	$800	$1,000	$81,500
Traffic Monitoring Cameras	$0	$0	$250	$600	$3,300
Traffic Detector Stations/ Site-Loops/Radar	$0	$0	$125 (Loops) $150 (Radar)	$600 (Loops) $400 (Radar)	$3,250 (Loops) $6,500 (Radar)
E-ZPass Readers	$550	$0	$0	$0	$12,500
Reversible Road Gates	$0	$225	$200	$1,500	$9,500
Ramp Meters	$0	$0	$150	$350	$6,000
Road Weather Information Systems Sites	$400	$0	$5,000	$20,000	$90,000
Automatic Traffic Recorders Sensors	$400	$200	$1,250	$0	$30,000
Weigh-In-Motion System Sites Senors	$400	$200	$1,250	$0	$150,000

Figures C-16 through C-39 shows the annual treatment distributions for the LCP approaches evaluated for each ITS asset.

Figure C-16: Annual Maintenance Fractions for Fiber Communication Network Miles - Current Approach

CURRENT APPROACH TREATMENTS	GOOD	FAIR	POOR	BEYOND USEFUL SERVICE LIFE
Routine Maintenance	0%	0%	0%	0%
Preventive Maintenance	0%	0%	0%	0%
Minor Rehabilitation	0%	0.2%	0%	0%
Major Rehabilitation	0%	0%	0.2%	0%
Replacement	0%	0%	0%	10%

Figure C-17: Annual Maintenance Fractions for Fiber Communication Network Miles - Desired Approach

CURRENT APPROACH TREATMENTS	GOOD	FAIR	POOR	BEYOND USEFUL SERVICE LIFE
Routine Maintenance	0%	0%	0%	0%
Preventive Maintenance	0%	0%	0%	0%
Minor Rehabilitation	0%	2%	0%	0%
Major Rehabilitation	0%	0%	2%	0%
Replacement	0%	0%	67.5%	100%

Figure C-18: Current Approach Annual Maintenance Fractions for Fiber Network Shelters - Current Approach

CURRENT APPROACH TREATMENTS	GOOD	FAIR	POOR	BEYOND USEFUL SERVICE LIFE
Routine Maintenance	0%	0%	0%	0%
Preventive Maintenance	50%	75%	100%	100%
Minor Rehabilitation	5%	25%	35%	35%
Major Rehabilitation	3%	25%	35%	35%
Replacement	0%	0%	5%	70%

Figure C-19: Current Approach Annual Maintenance Fractions for Fiber Network Shelters - Desired Approach

CURRENT APPROACH TREATMENTS	GOOD	FAIR	POOR	BEYOND USEFUL SERVICE LIFE
Routine Maintenance	0%	0%	0%	0%
Preventive Maintenance	50%	75%	100%	100%
Minor Rehabilitation	5%	25%	26%	0%
Major Rehabilitation	3%	25%	26%	0%
Replacement	0%	0%	55.5%	100%

Figure C-20: Annual Maintenance Fractions for Traffic Management System Cabinet - Current Approach

CURRENT APPROACH TREATMENTS	GOOD	FAIR	POOR	BEYOND USEFUL SERVICE LIFE
Routine Maintenance	100%	100%	100%	100%
Preventive Maintenance	0%	0%	0%	0%
Minor Rehabilitation	20%	30%	20%	0%
Major Rehabilitation	0%	10%	5%	0.5%
Replacement	0%	0%	0%	80%

Figure C-21: Annual Maintenance Fractions for Traffic Management System Cabinet - Desired Approach

CURRENT APPROACH TREATMENTS	GOOD	FAIR	POOR	BEYOND USEFUL SERVICE LIFE
Routine Maintenance	200%	200%	200%	200%
Preventive Maintenance	0%	0%	0%	0%
Minor Rehabilitation	40%	20%	20%	0%
Major Rehabilitation	0%	10%	5%	0.5%
Replacement	0%	0%	24%	99.5%

Figure C-22: Annual Maintenance Fractions for Dynamic Message Signs - Current Approach

CURRENT APPROACH TREATMENTS	GOOD	FAIR	POOR	BEYOND USEFUL SERVICE LIFE
Routine Maintenance	100%	100%	100%	10%
Preventive Maintenance	100%	100%	100%	10%
Minor Rehabilitation	3%	100%	100%	5%
Major Rehabilitation	3%	60%	100%	5%
Replacement	0%	0%	5%	90%

Figure C-23: Annual Maintenance Fractions for Dynamic Message Signs - Desired Approach

CURRENT APPROACH TREATMENTS	GOOD	FAIR	POOR	BEYOND USEFUL SERVICE LIFE
Routine Maintenance	200%	200%	200%	200%
Preventive Maintenance	200%	200%	200%	200%
Minor Rehabilitation	3%	100%	20%	0%
Major Rehabilitation	3%	60%	20%	0%
Replacement	0%	0%	56.5%	100%

Figure C-24: Annual Maintenance Fractions for Traffic Monitoring Cameras - Current Approach

CURRENT APPROACH TREATMENTS	GOOD	FAIR	POOR	BEYOND USEFUL SERVICE LIFE
Routine Maintenance	0%	0%	0%	0%
Preventive Maintenance	0%	0%	0%	0%
Minor Rehabilitation	10%	20%	30%	0%
Major Rehabilitation	5%	10%	10%	0%
Replacement	0%	0%	5%	100%

Figure C-25: Annual Maintenance Fractions for Traffic Monitoring Cameras - Desired Approach

CURRENT APPROACH TREATMENTS	GOOD	FAIR	POOR	BEYOND USEFUL SERVICE LIFE
Routine Maintenance	100%	100%	100%	0%
Preventive Maintenance	0%	0%	0%	0%
Minor Rehabilitation	20%	30%	40%	0%
Major Rehabilitation	5%	10%	10%	0%
Replacement	0%	0%	23%	100%

Figure C-26: Annual Maintenance Fractions for Traffic Detector Stations/Site-Loops/Radar - Current Approach

CURRENT APPROACH TREATMENTS	FUNCTIONAL	NON-FUNCTIONAL
Routine Maintenance	0% (Loops) 0% (Radar)	0% (Loops) 0% (Radar)
Preventive Maintenance	0% (Loops) 0% (Radar)	0% (Loops) 0% (Radar)
Minor Rehabilitation	15% (Loops) 0% (Radar)	0% (Loops) 0% (Radar)
Major Rehabilitation	15% (Loops) 1% (Radar)	0% (Loops) 0% (Radar)
Replacement	0% (Loops) 0% (Radar)	30% (Loops) 88% (Radar)

Figure C-27: Annual Maintenance Fractions for Traffic Detector Stations/Site-Loops/Radar - Desired Approach

CURRENT APPROACH TREATMENTS	FUNCTIONAL	NON-FUNCTIONAL
Routine Maintenance	0% (Loops) 0% (Radar)	0% (Loops) 0% (Radar)
Preventive Maintenance	0% (Loops) 0% (Radar)	0% (Loops) 0% (Radar)
Minor Rehabilitation	15% (Loops) 20% (Radar)	0% (Loops) 0% (Radar)
Major Rehabilitation	15% (Loops) 1% (Radar)	0% (Loops) 0% (Radar)
Replacement	0% (Loops) 0% (Radar)	88% (Loops) 88% (Radar)

Figure C-28: Annual Maintenance Fractions for E-ZPass Readers - Current Approach

CURRENT APPROACH TREATMENTS	GOOD	FAIR	POOR	BEYOND USEFUL SERVICE LIFE
Routine Maintenance	50%	100%	100%	100%
Preventive Maintenance	0%	0%	0%	0%
Minor Rehabilitation	0%	0%	0%	0%
Major Rehabilitation	0%	0%	0%	0%
Replacement	0%	0%	0%	100%

Figure C-29: Annual Maintenance Fractions for E-ZPass Readers - Desired Approach

CURRENT APPROACH TREATMENTS	GOOD	FAIR	POOR	BEYOND USEFUL SERVICE LIFE
Routine Maintenance	50%	100%	100%	100%
Preventive Maintenance	0%	0%	0%	0%
Minor Rehabilitation	0%	0%	0%	0%
Major Rehabilitation	0%	0%	0%	0%
Replacement	0%	0%	87%	100%

Figure C-30: Annual Maintenance Fractions for Reversible Road Gates - Current Approach

CURRENT APPROACH TREATMENTS	GOOD	FAIR	POOR	BEYOND USEFUL SERVICE LIFE
Routine Maintenance	0%	0%	0%	0%
Preventive Maintenance	100%	100%	100%	100%
Minor Rehabilitation	100%	40%	70%	39.5%
Major Rehabilitation	0%	60%	30%	0.5%
Replacement	0%	0%	0%	60%

Figure C-31: Annual Maintenance Fractions for Reversible Road Gates - Desired Approach

CURRENT APPROACH TREATMENTS	GOOD	FAIR	POOR	BEYOND USEFUL SERVICE LIFE
Routine Maintenance	0%	0%	0%	0%
Preventive Maintenance	100%	100%	100%	100%
Minor Rehabilitation	200%	25%	70%	14.5%
Major Rehabilitation	0%	75%	15%	0.5%
Replacement	0%	0%	15%	75%

Figure C-32: Annual Maintenance Fractions for Ramp Meters - Current Approach

CURRENT APPROACH TREATMENTS	GOOD	FAIR	POOR
Routine Maintenance	0%	0%	0%
Preventive Maintenance	0%	0%	0%
Minor Rehabilitation	0%	0%	2.5%
Major Rehabilitation	0%	0%	1%
Replacement	0%	0%	96.5%

Figure C-33: Annual Maintenance Fractions for Ramp Meters - Desired Approach

CURRENT APPROACH TREATMENTS	GOOD	FAIR	POOR
Routine Maintenance	0%	0%	0%
Preventive Maintenance	0%	0%	0%
Minor Rehabilitation	0%	0%	2.5%
Major Rehabilitation	0%	0%	1%
Replacement	0%	0%	96.5%

Figure C-34: Annual Maintenance Fractions for Road Weather Information Systems Sites - Current Approach

CURRENT APPROACH TREATMENTS	GOOD	FAIR	POOR	BEYOND USEFUL SERVICE LIFE
Routine Maintenance	200%	200%	200%	0%
Preventive Maintenance	0%	0%	0%	0%
Minor Rehabilitation	20%	20%	20%	0%
Major Rehabilitation	16.7%	16.7%	16.7%	0%
Replacement	0%	0%	0%	90%

Figure C-35: Annual Maintenance Fractions for Road Weather Information Systems Sites - Desired Approach

CURRENT APPROACH TREATMENTS	GOOD	FAIR	POOR	BEYOND USEFUL SERVICE LIFE
Routine Maintenance	200%	200%	200%	0%
Preventive Maintenance	0%	0%	0%	0%
Minor Rehabilitation	20%	20%	10.3%	0%
Major Rehabilitation	16.7%	16.7%	16.7%	0%
Replacement	0%	0%	73%	100%

Figure C-36: Annual Maintenance Fractions for Automatic Traffic Recorders Sensors - Current Approach

CURRENT APPROACH TREATMENTS	GOOD	FAIR	POOR	BEYOND USEFUL SERVICE LIFE
Routine Maintenance	5%	5%	5%	0%
Preventive Maintenance	100%	100%	100%	0%
Minor Rehabilitation	0%	1%	1.5%	0%
Major Rehabilitation	0%	0%	0%	0%
Replacement	0%	2%	5%	90%

Figure C-37: Annual Maintenance Fractions for Automatic Traffic Recorders Sensors - Desired Approach

CURRENT APPROACH TREATMENTS	GOOD	FAIR	POOR	BEYOND USEFUL SERVICE LIFE
Routine Maintenance	5%	5%	5%	0%
Preventive Maintenance	100%	100%	100%	0%
Minor Rehabilitation	0%	1%	1.5%	0%
Major Rehabilitation	0%	0%	0%	0%
Replacement	0%	2%	62.3%	100%

Figure C-38: Annual Maintenance Fractions for Weigh-In-Motion System Sites Senors - Current Approach

CURRENT APPROACH TREATMENTS	GOOD	FAIR	POOR	BEYOND USEFUL SERVICE LIFE
Routine Maintenance	5%	5%	5%	0%
Preventive Maintenance	100%	100%	100%	0%
Minor Rehabilitation	0%	1%	1.5%	0%
Major Rehabilitation	0%	0%	0%	0%
Replacement	0%	2%	5%	90%

Figure C-39: Annual Maintenance Fractions for Weigh-In-Motion System Sites Senors - Desired Approach

CURRENT APPROACH TREATMENTS	GOOD	FAIR	POOR	BEYOND USEFUL SERVICE LIFE
Routine Maintenance	5%	5%	5%	0%
Preventive Maintenance	100%	100%	100%	0%
Minor Rehabilitation	0%	1%	1.5%	0%
Major Rehabilitation	0%	0%	0%	0%
Replacement	0%	2%	56%	100%

Figure C-40 shows the treatment impact matrix for ITS infrastructure. It reflects the change in conditions expected after each treatment has been applied. Key assumptions are listed below:

- Routine and preventive maintenance actions have no impact on asset condition.
- For assets in poor or better condition, minor rehabilitation improves asset condition by one condition state (fair to good, poor to fair).
- Major rehabilitation improves conditions by two condition states (beyond useful service life to fair and poor to good).
- Replacement restores assets to as-built condition.

Figure C-40: Treatment Impact Matrix for ITS Infrastructure Assets

(Treatments and Resulting Asset Condition after Treatment Application)

Note: For dynamic message signs and fiber network shelter assets, minor rehabilitation and major rehabilitation treatments have no impact in condition.

CURRENT CONDITION	ROUTINE MAINTENANCE	PREVENTIVE MAINTENANCE	MINOR REHAB	MAJOR REHAB	REPLACEMENT
Good	Good	Good	N/A	N/A	N/A
Fair	Fair	Fair	Good	N/A	N/A
Poor	Poor	Poor	Fair	Good	Good
Beyond Useful Service Life	Beyond Useful Service Life	Beyond Useful Service Life	Beyond Useful Service Life	Fair	Good

NOISE WALLS

WOOD PANEL NOISE WALLS

Figure C-41 presents deterioration model for wood panel noise walls. The same model is used for both the current and desired approaches. An explanation of the Markov transition matrix and deterioration from one condition state to another is in Figure C-3.

Figure C-41: Deterioration Model for Wood Panel Noise Walls

TRANSITION STATES	YEARS	GOOD	FAIR	POOR	VERY POOR
Good to Fair	35	98%	2%	N/A	N/A
Fair to Poor	20	N/A	96.6%	3.4%	N/A
Poor to Very Poor	10	N/A	N/A	93.3%	6.7%

Figures C-42 and C-43 present the unit costs and annual treatment distributions for the current and desired approaches, respectively.

Figure C-42: Annual Treatment Distributions for Wood Panel Noise Walls - Current Approach

TREATMENT	% ANNUALLY TREATED IN GOOD CONDITION	% ANNUALLY TREATED IN FAIR CONDITION	% ANNUALLY TREATED IN POOR CONDITION	% ANNUALLY TREATED IN VERY POOR CONDITION	UNIT COST ($ PER ASSET)
Structural Inspection	10%	10%	10%	10%	$500
Reactive Maintenance	2%	2%	2%	2%	$15,000
Out of Cycle Inspection	0%	0%	0%	0%	$500
Re-Planking	0%	0%	16%	16%	$375,000
Splash Zone Sealing	0%	0%	0%	0%	$8,500
Replacement	0%	0%	4%	4%	$800,000

Figure C-43: Annual Treatment Distributions for Wood Panel Noise Walls - Desired Approach

TREATMENT	% ANNUALLY TREATED IN GOOD CONDITION	% ANNUALLY TREATED IN FAIR CONDITION	% ANNUALLY TREATED IN POOR CONDITION	% ANNUALLY TREATED IN VERY POOR CONDITION	UNIT COST ($ PER ASSET)
Structural Inspection	10%	10%	10%	10%	$500
Reactive Maintenance	2%	2%	2%	2%	$15,000
Out of Cycle Inspection	0%	0%	10%	10%	$500
Re-Planking	0%	0%	12%	12%	$375,000
Splash Zone Sealing	0%	20%	20%	20%	$8,500
Replacement	0%	0%	8%	8%	$800,000

CONCRETE NOISE WALLS

Figure C-44 presents deterioration models for concrete noise walls. The same model is used for both the current and desired approaches.

Figure C-44: Deterioration Model for Wood Panel Noise Walls

TRANSITION STATES	YEARS	GOOD	FAIR	POOR	VERY POOR
Good to Fair	50	98.6%	1.4%	N/A	N/A
Fair to Poor	20	N/A	96.6%	3.4%	N/A
Poor to Very Poor	10	N/A	N/A	93.3%	6.7%

Figures C-45 and C-46 present the unit costs and annual treatment distributions for the current and desired approaches, respectively.

Figure C-45: Annual Treatment Distributions for Concrete Noise Walls - Current Approach

TREATMENT	% ANNUALLY TREATED IN GOOD CONDITION	% ANNUALLY TREATED IN FAIR CONDITION	% ANNUALLY TREATED IN POOR CONDITION	% ANNUALLY TREATED IN VERY POOR CONDITION	UNIT COST ($ PER ASSET)
Structural Inspection	10%	10%	10%	10%	$500
Reactive Maintenance	0%	0%	0%	0%	$0
Out of Cycle Inspection	0%	0%	0%	0%	$500
Re-Planking	0%	0%	20%	20%	$400,000
Splash Zone Sealing	0%	0%	0%	0%	$15,000
Replacement	0%	0%	0%	0%	$800,000

Figure C-46: Annual Treatment Distributions for Concrete Noise Walls - Desired Approach

TREATMENT	% ANNUALLY TREATED IN GOOD CONDITION	% ANNUALLY TREATED IN FAIR CONDITION	% ANNUALLY TREATED IN POOR CONDITION	% ANNUALLY TREATED IN VERY POOR CONDITION	UNIT COST ($ PER ASSET)
Structural Inspection	10%	10%	10%	10%	$500
Reactive Maintenance	2%	2%	2%	2%	$30,000
Out of Cycle Inspection	0%	0%	10%	10%	$500
Re-Planking	0%	0%	12%	12%	$400,000
Splash Zone Sealing	0%	20%	20%	20%	$15,000
Replacement	0%	0%	8%	8%	$800,000

TREATMENT IMPACT MATRIX

Figure C-47 shows the treatment impact matrix for noise walls (both wood panel and concrete). It reflects the change in conditions expected after each treatment has been applied. Key assumptions are listed below:

- Structural inspection, reactive maintenance, out-of-cycle inspection, and splash zone sealing do not have any impact on asset condition.
- Complete replacement is the only treatment action that has a significant impact on asset condition, especially assets in poor and very poor condition.
- Re-planking (for wood panel noise walls) and minor rehabilitation (for concrete noise walls) results in:
  - Significant condition improvement for assets in fair condition.
  - Small condition improvements for assets in poor and very poor condition.

Figure C-47: Treatment Impact Matrix for Noise Walls

(Treatments and Resulting Asset Condition after Treatment Application)

CURRENT CONDITION	STRUCTURAL INSPECTION	REACTIVE MAINTENANCE	OUT OF CYCLE INSPECTION	RE-PLANKING (WOOD PANEL) / MINOR REHAB (CONCRETE)	SPLASH ZONE SEALING	REPLACEMENT
Good	Good	Good	Good	N/A	Good	N/A
Fair	Fair	Fair	Fair	90% Good	Fair	N/A
Poor	Poor	Poor	Poor	20% Good/ 80% Fair	Poor	Good
Very Poor	Very Poor	Very Poor	Very Poor	10% Good/ 50% Fair/ 40% Poor	Very Poor	Good

OVERHEAD SIGN STRUCTURES

Figure C-48 presents the deterioration models used for each LCP approach evaluated.

The desired approach's extended transition state periods are attributed to an increase in out-of-cycle Inspections, which will help identify and monitor issues before they cause structures to deteriorate in condition. The change also increases the frequency of nut tightening, rehabilitation, and replacement, ensuring that more structures will be assigned higher condition states, improving overall inventory health. An explanation of the Markov transition matrix and deterioration from one condition state to another is in Figure C-3.

Figure C-48: Deterioration Models for Overhead Sign Structures

APPROACH	TRANSITION STATES	YEARS	GOOD	FAIR	POOR
Current	Good to Fair	20	96.6%	3.4%	N/A
Current	Fair to Poor	10	N/A	93.3%	6.7%
Desired	Good to Fair	25	97.3%	2.7%	N/A
Desired	Fair to Poor	12	N/A	94.4%	5.6%

Figures C-49 and C-50 present the unit costs and annual treatment distributions for the current and desired approaches, respectively.

Figure C-49: Annual Treatment Distributions for Overhead Sign Structures - Current Approach

TREATMENT	% ANNUALLY TREATED IN GOOD CONDITION	% ANNUALLY TREATED IN FAIR CONDITION	% ANNUALLY TREATED IN POOR CONDITION	UNIT COST ($ PER ASSET)
Reactive Maintenance	0.2%	0.2%	0.2%	$90,000
Structural Inspection	20%	20%	20%	$200
Out of cycle inspection	0%	0%	0%	$200
Tighten Nuts	0%	0%	7.5%	$800
Major rehab	0%	0%	5%	$19,000
Replacement	0%	0%	3%	$125,000

Figure C-50: Annual Treatment Distributions for Overhead Sign Structures - Desired Approach

TREATMENT	% ANNUALLY TREATED IN GOOD CONDITION	% ANNUALLY TREATED IN FAIR CONDITION	% ANNUALLY TREATED IN POOR CONDITION	UNIT COST ($ PER ASSET)
Reactive Maintenance	0.2%	0.2%	0.2%	$90,000
Structural Inspection	20%	20%	20%	$200
Out of cycle inspection	0%	0%	10%	$200
Tighten Nuts	0%	0%	10%	$800
Major rehab	0%	0%	7%	$19,000
Replacement	0%	0%	5%	$125,000

Figure C-51 shows the treatment impact matrix for overhead sign structures. It reflects the change in conditions expected after each treatment has been applied. Key assumptions are listed below:.

- Treatments such as reactive maintenance, structural inspection, and out-of-cycle inspection have no impact on condition.
- Treatments such as tightening nuts improve assets in poor condition to either good (75% of the time) or fair (25% of the time) condition.
- Major rehabilitation and replacement treatments completely restore assets in poor condition to good condition.

Figure C-51: Treatment Impact Matrix for Overhead Sign Structures

(Treatments and Resulting Asset Condition after Treatment Application)

CURRENT CONDITION	REACTIVE MAINTENANCE	STRUCTURAL INSPECTION	OUT-OF-CYCLE INSPECTION	TIGHTEN NUTS	MAJOR REHAB	REPLACEMENT
Good	Good	Good	Good	N/A	N/A	N/A
Fair	Fair	Fair	Fair	N/A	N/A	N/A
Poor	Poor	Poor	Poor	75% to Good and 25% to Fair	Good	Good

PEDESTRIAN INFRASTRUCTURE

CURB RAMPS

Figure C-52 presents the deterioration model for curb ramps. An explanation of the Markov transition matrix and deterioration from one condition state to another is in Figure C-3.

Figure C-52: Deterioration Model for Curb Ramps

TRANSITION STATES	YEARS	COMPLIANT	NON-COMPLIANT
Compliant to Non-Compliant	10	93.3%	6.7%

Figures C-53 and C-54 present the unit costs and annual maintenance fractions for the current and desired approaches, respectively.

Figure C-53: Annual Maintenance Fractions for Curb Ramps - Current Approach

TREATMENT	% ANNUALLY TREATED IN COMPLIANT CONDITION	% ANNUALLY TREATED IN NON-COMPLIANT CONDITION	UNIT COST ($ PER ASSET)
Inspection	5%	5%	$35
Grinding	7.5%	6%	$150
Slab Jacking	7.5%	6%	$250
Vegetation Removal	7.5%	6%	$50
Replacement	4.5%	10.00%	$5,000

Figure C-54: Annual Maintenance Fractions for Curb Ramps - Desired Approach

TREATMENT	% ANNUALLY TREATED IN COMPLIANT CONDITION	% ANNUALLY TREATED IN NON-COMPLIANT CONDITION	UNIT COST ($ PER ASSET)
Inspection	6%	6%	$35
Grinding	8.5%	7%	$200
Slab Jacking	8.5%	7%	$250
Vegetation Removal	8.5%	7%	$50
Replacement	4.5%	35%	$5,000

Figure C-55 shows the treatment impact matrix for curb ramps. Inspection has no impact on condition. Grinding, slab jacking, and vegetation removal result in fractional condition improvements and replacement restores the asset to a compliant condition state.

Figure C-55: Treatment Impact Matrix for Curb Ramps

(Treatments and Resulting Asset Condition after Treatment Application)

CURRENT CONDITION	INSPECTION	GRINDING	SLAB JACKING	VEGETATION REMOVAL	REPLACEMENT
Compliant	Compliant	Compliant	Compliant	Compliant	Compliant
Non - Compliant	Non - Compliant	75% Compliant	75% Compliant	85% Compliant	Compliant

SIDEWALKS

Key Assumption:

A significant assumption for sidewalks is that the network growth rate is 1% annually instead of 3% (used for all other assets). This difference is because sidewalk investments are targeted at existing infrastructure. Therefore, the 1% growth rate means fewer sidewalks are added to the inventory over time.

Figure C-56 presents the deterioration model for sidewalks. An explanation of the Markov transition matrix and deterioration from one condition state to another is in Figure C-3.

Figure C-56: Deterioration Model for Sidewalks

TRANSITION STATES	YEARS	COMPLIANT	NON-COMPLIANT
Compliant to Non-Compliant	10	93.3%	6.7%

Figures C-57 and C-58 present the unit costs and annual maintenance fractions for the current and desired approaches, respectively.

Figure C-57: Annual Maintenance Fractions for Sidewalks - Current Approach

TREATMENT	% ANNUALLY TREATED IN COMPLIANT CONDITION	% ANNUALLY TREATED IN NON-COMPLIANT CONDITION	UNIT COST ($ PER ASSET)
Inspection	0%	0.1%	$0.64
Grinding	0%	0.2%	$2.73
Slab Jacking	0%	0.2%	$4.55
Vegetation Removal	0%	0.2%	$0.91
Major Rehabilitation (Panel Replacement)	0%	2.5%	$8.00
Replacement	0%	10.3%	$8.00

Figure C-58: Annual Maintenance Fractions for Sidewalks - Desired Approach

TREATMENT	% ANNUALLY TREATED IN COMPLIANT CONDITION	% ANNUALLY TREATED IN NON-COMPLIANT CONDITION	UNIT COST ($ PER ASSET)
Inspection	1%	1%	$0.64
Grinding	1%	1%	$2.73
Slab Jacking	1%	1%	$4.55
Vegetation Removal	1%	1%	$0.91
Major Rehabilitation (Panel Replacement)	1%	15%	$8.00
Replacement	1%	37%	$8.00

Figure C-59 shows the treatment impact matrix for sidewalks. Inspection has no impact on the condition. Grinding, slab jacking, and vegetation removal result in fractional condition improvements, and replacement restores the asset to a compliant condition state.

Figure C-59: Treatment Impact Matrix for Curb Ramps

(Treatments and Resulting Asset Condition after Treatment Application)

CURRENT CONDITION	INSPECTION	GRINDING	SLAB JACKING	VEGETATION REMOVAL	MAJOR REHAB	REPLACEMENT
Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant
Non - Compliant	Non - Compliant	75% compliant	90% compliant	80% Compliant	Compliant	Compliant

TRAFFIC SIGNALS

The deterioration model for signals is shown in figure C-60. The same model is used for each LCP approach evaluated. An explanation of the Markov transition matrix and deterioration from one condition state to another is in Figure C-3.

Figure C-60: Deterioration Model for Traffic Signals

TRANSITION STATES	YEARS	GOOD	FAIR	POOR	BEYOND USEFUL SERVICE LIFE
Good to Fair	13	79.4%	20.6%	N/A	N/A
Fair to Poor	11	N/A	76.2%	23.8%	N/A
Poor to Beyond Useful Service Life	6	N/A	N/A	60.7%	39.3%

Figures C-61 and C-62 present the unit costs and annual treatment distributions for the current and desired approaches, respectively.

Figure C-61: Annual Maintenance Fractions for Traffic Signals - Current Approach

TREATMENT	% ANNUALLY TREATED IN GOOD CONDITION	% ANNUALLY TREATED IN FAIR CONDITION	% ANNUALLY TREATED IN POOR CONDITION	% ANNUALLY TREATED IN BEYOND USEFUL SERVICE LIFE CONDITION	UNIT COST ($ PER ASSET COUNT)
Structural Inspection	2%	10%	10%	5%	$1,000
Reactive Maintenance	25%	25%	25%	25%	$400
Operations Check	90%	90%	90%	90%	$100
Electrician Preventive Maintenance	30%	20%	20%	20%	$150
Electronic Preventive Maintenance	50%	50%	50%	50%	$200
Replace LED Indications	0%	10%	10%	2%	$1,400
Replace Electronics	0%	30%	30%	5%	$12,000
Complete Replacement	0%	0%	0%	5%	$450,000
PM Treatment (Transformer, bracketing, ped heads)	0%	10%	15%	5%	$1,000

Figure C-62: Annual Maintenance Fractions for Traffic Signals - Desired Approach

TREATMENT	% ANNUALLY TREATED IN GOOD CONDITION	% ANNUALLY TREATED IN FAIR CONDITION	% ANNUALLY TREATED IN POOR CONDITION	% ANNUALLY TREATED IN BEYOND USEFUL SERVICE LIFE CONDITION	UNIT COST ($ PER ASSET COUNT)
Structural Inspection	2%	10%	10%	5%	$1,000
Reactive Maintenance	25%	25%	25%	25%	$400
Operations Check	100%	100%	100%	100%	$100
Electrician Preventive Maintenance	50%	50%	50%	50%	$150
Electronic Preventive Maintenance	100%	100%	100%	100%	$200
Replace LED Indications	10%	10%	10%	10%	$1,400
Replace Electronics	0%	30%	30%	5%	$12,000
Complete Replacement	0%	0%	2%	7%	$450,000
PM Treatment (Transformer, bracketing, ped heads)	0%	10%	15%	2%	$1,000

Figure C-62 shows the treatment impact matrix for signals. It reflects the change in conditions expected after each treatment has been applied. Key assumptions are listed below:

- Structural inspection, reactive maintenance, operations check, electrical and electronic preventive maintenance, LED indication and electronic replacements do not have any impact on asset condition.
- Complete replacement is the only treatment action that has a significant impact on asset condition, especially assets in poor and beyond useful service life condition.
- The generic Preventive Maintenance treatments result in small condition improvements for assets in poor and beyond useful service life condition states. For assets in fair condition, the Preventive Maintenance treatments restore the condition to good condition.

Figure C-62: Treatment Impact Matrix for Traffic Signals

(Treatments and Resulting Asset Condition after Treatment Application)

Note: The treatments are structural inspection, reactive maintenance, operations check, electrical preventive maintenance, electronic preventive maintenance, replace LED indications, replace electronics, complete replacement, PM treatment.

CURRENT CONDITION	STRUCTURAL INSPECTION	REACTIVE MAINTENANCE	OPS. CHECK	ELECTRICAL AND ELECTRONIC PM	REPLACE LED AND ELECTRONICS	TOTAL REPLACE	PM TREAT
Good	Good	Good	Good	Good	Good	N/A	N/A
Fair	Fair	Fair	Fair	Fair	Fair	N/A	Good
Poor	Poor	Poor	Poor	Poor	Poor	Good	20% Good /30% Fair
Beyond Useful Service Life	Beyond Useful Service Life	Beyond Useful Service Life	Beyond Useful Service Life	Beyond Useful Service Life	Beyond Useful Service Life	Good	10% Good /5% Fair /85% Poor

LIGHTING

The deterioration model for signals is shown in figure C-63. The same model is used for each LCP approach evaluated. An explanation of the Markov transition matrix and deterioration from one condition state to another is in Figure C-3.

Figure C-63: Deterioration Model for Lighting

TRANSITION STATES	YEARS	GOOD	FAIR	POOR	BEYOND USEFUL SERVICE LIFE
Good to Fair	13	79.4%	20.6%	N/A	N/A
Fair to Poor	11	N/A	76.2%	23.8%	N/A
Poor to Beyond Useful Service Life	6	N/A	N/A	60.7%	39.3%

Figures C-64 and C-65 present the unit costs and annual treatment distributions for the current and desired approaches, respectively.

Figure C-64: Annual Maintenance Fractions for Lighting - Current Approach

TREATMENT	% ANNUALLY TREATED IN GOOD CONDITION	% ANNUALLY TREATED IN FAIR CONDITION	% ANNUALLY TREATED IN POOR CONDITION	% ANNUALLY TREATED IN BEYOND USEFUL SERVICE LIFE CONDITION	UNIT COST ($ PER ASSET COUNT)
Knockdowns and Replacements	1.5%	1.5%	1.5%	1.5%	$4,000
Reactive Maintenance	2%	2.5%	3%	3.5%	$1,000
Electrical Inspection	1%	1%	1%	1%	$55
Replace Luminaires	10%	10%	10%	10%	$500
Structural Inspection	1%	10%	10%	0%	$140
PM Treatment	0%	1%	1%	0%	$2,480
Complete Replacement	0%	0%	0%	11%	$6,500

Figure C-65: Annual Maintenance Fractions for Lighting - Desired Approach

TREATMENT	% ANNUALLY TREATED IN GOOD CONDITION	% ANNUALLY TREATED IN FAIR CONDITION	% ANNUALLY TREATED IN POOR CONDITION	% ANNUALLY TREATED IN BEYOND USEFUL SERVICE LIFE CONDITION	UNIT COST ($ PER ASSET COUNT)
Knockdowns and Replacements	1.5%	1.5%	1.5%	1.5%	$4,000
Reactive Maintenance	2%	2.5%	3%	3.5%	$1,000
Electrical Inspection	20%	20%	20%	50%	$55
Replace Luminaires	10%	10%	10%	10%	$500
Structural Inspection	10%	10%	10%	50%	$140
PM Treatment	0%	1%	1%	0%	$2,480
Complete Replacement	0%	0%	0%	80%	$6,500

Figure C-66 shows the treatment impact matrix for lighting. It reflects the change in conditions expected after each treatment has been applied. Key assumptions are listed below:

- For assets in poor or beyond useful service life conditions, knockdowns improve the conditions one level and for assets in a fair condition, 50% of the assets are improved to good condition.
- Reactive maintenance, electrical inspection, replacing luminaries and structural inspection have no impact on asset conditions.
- Preventive maintenance treatment (a generic maintenance treatment) is assumed to improve assets from fair to good conditions and also results in small condition improvements for assets in poor or beyond useful service life conditions.
- Complete replacement restores the assets to an as-built condition.

Figure C-66: Treatment Impact Matrix for Lighting

(Treatments and Resulting Asset Condition after Treatment Application)

CURRENT CONDITION	KNOCK-DOWNS	REACTIVE MAINTENANCE	ELECTRICAL INSPECTION	REPLACE LUMINAIRES	STRUCTURAL INSPECTION	PM TREATMENT	COMPLETE REPLACEMENT
Good	Good	Good	Good	Good	Good	N/A	N/A
Fair	50% Good	Fair	Fair	Fair	Fair	Good	Good
Poor	Fair	Poor	Poor	Poor	Poor	20% Good/ 30% Fair	Good
Beyond Useful Service Life	Poor	Beyond Useful Service Life	Beyond Useful Service Life	Beyond Useful Service Life	Beyond Useful Service Life	10% Good/ 5% Fair/85% Poor	Good

HIGH-MAST LIGHT TOWERS

Figure C-67 shows the deterioration model for high-mast light towers. An explanation of the Markov transition matrix and deterioration from one condition state to another is in Figure C-3.

Figure C-67: Deterioration Model for High- Mast Light Towers

TRANSITION STATES	YEARS	GOOD	FAIR	POOR	BEYOND USEFUL SERVICE LIFE
Good to Fair	40	98.3%	1.7%	N/A	N/A
Fair to Poor	10	N/A	93.3%	6.7%	N/A
Poor to Beyond useful service life	10	N/A	N/A	93.3%	6.7%

Figures C-68 and C-69 present the unit costs and annual treatment distributions for the current approach and desired approaches, respectively.

Figure C-68: Annual Maintenance Fractions for High-Mast Light Towers - Current Approach

TREATMENT	% ANNUALLY TREATED IN GOOD CONDITION	% ANNUALLY TREATED IN FAIR CONDITION	% ANNUALLY TREATED IN POOR CONDITION	% ANNUALLY TREATED IN BEYOND USEFUL SERVICE LIFE CONDITION	UNIT COST ($ PER ASSET COUNT)
Structural Inspection	0%	10%	10%	0%	$200
Tighten Nuts and Winch replacement	0%	2%	2%	0%	$250
Out of Cycle Inspection I (excluding Removal and Replacement)	0%	5%	0%	0%	$200
Out of Cycle Inspection II (including Removal and Replacement)	0%	0%	5%	0%	$110,000
Replace LED Luminaires	8.3%	8.3%	8.3%	8.3%	$2,400
Exercise Lowering Mechanism	0%	2%	3%	0%	$100
Removal and Replacement	0%	0%	2%	2%	$110,000

Figure C-69: Annual Maintenance Fractions for High-Mast Light Towers - Desired Approach

TREATMENT	% ANNUALLY TREATED IN GOOD CONDITION	% ANNUALLY TREATED IN FAIR CONDITION	% ANNUALLY TREATED IN POOR CONDITION	% ANNUALLY TREATED IN BEYOND USEFUL SERVICE LIFE CONDITION	UNIT COST ($ PER ASSET COUNT)
Structural Inspection	0%	10%	10%	0%	$200
Tighten Nuts and Winch replacement	0%	2%	2%	0%	$250
Out of Cycle Inspection I (excluding Removal and Replacement)	0%	5%	0%	0%	$200
Out of Cycle Inspection II (including Removal and Replacement)	0%	0%	5%	0%	$110,000
Replace LED Luminaires	8.3%	8.3%	8.3%	8.3%	$2,400
Exercise Lowering Mechanism	0%	2%	3%	0%	$100
Removal and Replacement	0%	0%	5%	5%	$110,000

Figure C-70 shows the treatment impact matrix for high-mast light towers. It reflects the change in conditions expected after each treatment has been applied. Key assumptions are listed below:

- Treatments such as structural inspection, replacement of LED luminaries, and exercise lowering mechanism have no impact on condition.
- Nut tightening and winch replacement restore the asset to a good condition.
- Out-of-cycle inspections:
    - Out of cycle inspection I does not include removal and replacement. This treatment is applied to assets in fair or better condition. When performed on assets in fair condition, most of the assets are expected to return to a good condition.
    - Out of cycle inspection II treatment includes removal and replacement. This treatment is applied to assets in poor or worse condition. This treatment restores the asset to a good condition.
- Removal and replacement restores assets in poor or worse condition to good condition.

Figure C-70: Treatment Impact Matrix for High-Mast Light Towers

(Treatments and Resulting Asset Condition after Treatment Application)

CURRENT CONDITION	STRUCTURAL INSPECTION	TIGHTEN NUTS AND WINCH REPLACEMENT	OUT OF CYCLE INSPECTION I	OUT OF CYCLE INSPECTION II	REPLACE LED	EXERCISE LOWERING MECHANISM	REMOVAL AND REPLACEMENT
Good	Good	N/A	Good	N/A	Good	Good	N/A
Fair	Good	Good	95% Good	N/A	Fair	Fair	N/A
Poor	Poor	Good	N/A	Good	Poor	Poor	Good
Beyond Useful Service Life	Beyond Useful Service Life	Good	N/A	Good	Beyond Useful Service Life	Beyond Useful Service Life	Good