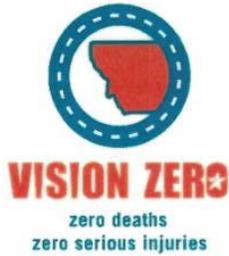


Transportation Asset Management Plan



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Montana Department of Transportation

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Steve Bullock, Governor

Michael T. Tooley, Director

June 24, 2019

Brian Hasselbach
Acting Division Administrator
Federal Highway Administration
585 Shepard Way
Helena, MT 59601

Mr. Hasselbach:

I am submitting the Montana Department of Transportation Risk Based Transportation Asset Management Plan (TAMP) for FHWA review and full certification as required by 23 USC Section 119(g).

As you know, MDT is responsible for providing safe and effective transportation systems for the traveling public, while supporting Montana's economic vitality and our citizens' quality of life. Making good investment decisions to preserve, protect, and maintain Montana's roads and bridges is critical for achieving and sustaining a state of good repair with the limited resources available. MDT began making investment decisions based on an asset management approach in the late 1990s, and with this submittal are addressing federal requirements while continuing to focus on best practices for managing Montana's transportation infrastructure needs.

MDT's TAMP considers physical conditions, life-cycle planning analysis, investment scenarios, and risks associated with Montana's National Highway System pavements and bridges and provides a roadmap for future investment strategies and expected levels of performance for these facilities. MDT's asset management plan emphasizes performing the right treatment at the right time with a focus on preservation and maintenance consistent with TranPlanMT – our long-range transportation policy plan.

Sincerely,

Mike Tooley
Director of Transportation



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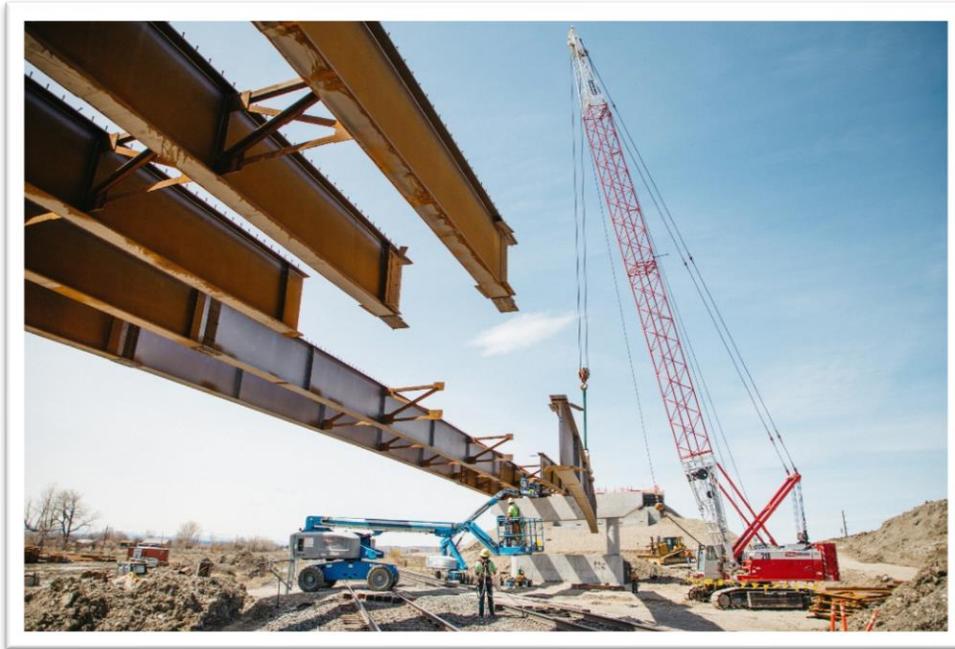
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1 EXECUTIVE SUMMARY

Introduction

In this era of increasingly constrained resources, effectively managing transportation assets is a vital function of state transportation agencies. The Montana Department of Transportation (MDT) is committed to managing the condition and performance of Montana's state transportation system and strives to achieve state of good repair (SOGR) through effectively investing those limited resources.

MDT's asset management history began in earnest in the late 1990's with the implementation of the Performance Programming Process (P3). P3 is based in Department policy and procedures to develop an optimal investment plan that achieves progress toward performance goals established in the state's long-range transportation policy plan, TranPlanMT.

Following the passage of the Moving Ahead for Progress in the 21st Century Act (MAP-21), MDT developed a risk-based transportation asset management plan (TAMP). The initial TAMP, adopted in 2015, bolstered MDT's existing asset management processes.

After FHWA adopted final rules for state risk-based asset management plans in late 2016, MDT initiated an update to the 2015 TAMP for Federal compliance. This update expands MDT's TAMP process description, analysis, and consideration of life cycle planning, performance gaps, non-condition related performance, and risk in developing recommended investment strategies. The 2018 TAMP supports achieving short-term performance targets and making progress toward MDT's vision for Interstate and Non-Interstate National Highway System (NHS) pavements and bridges.

The 2018 TAMP remains based on MDT's statewide policy and planning goals with decision making and analysis support provided by Department data management systems, procedures, and staff expertise.

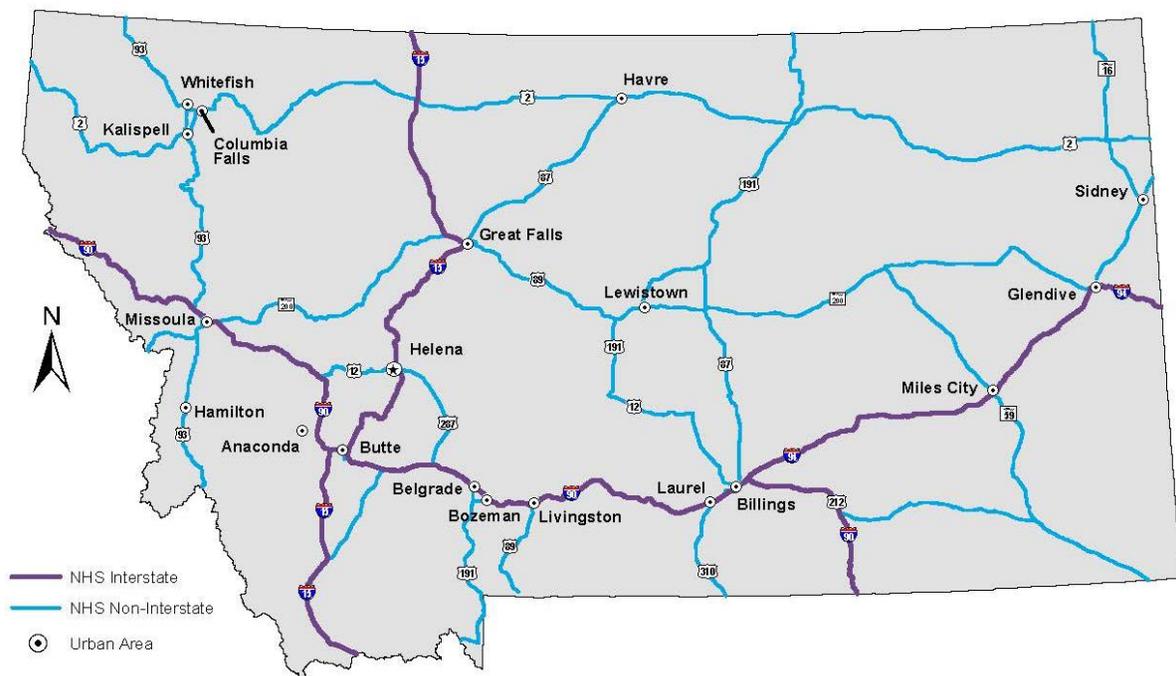
The TAMP documents MDT business practices. It also aligns the Department's P3, data collection, and reporting used for asset management with related Federal requirements. The foundation of P3 continues to center on MDT policy direction of providing the right treatment at the right time with the strong emphasis of preserving the condition and performance of existing transportation infrastructure.

To ensure compliance with Federal requirements for Interstate and Non-Interstate NHS pavements and bridges, the TAMP addresses the following:

- ★ Process to complete a performance gap analysis and identify strategies to close gaps;
- ★ Process to complete life cycle planning;
- ★ Process to complete risk analysis and develop a mitigation plan;
- ★ Process to develop a financial plan covering at least a 10-year period;
- ★ Process to develop investment strategies;
- ★ Process of obtaining necessary data from other NHS owners; and
- ★ Process for ensuring the TAMP is developed with the best available data and that the state has used bridge and pavement management systems.

NHS System Extent and Condition

There is one bridge and four short segments of NHS pavement, totaling less than 2 miles, that are maintained by local entities and reported as local ownership. MDT, however, is responsible for inspection, data collection and reporting, and project identification and development on all NHS facilities. Therefore, there was no need for MDT to coordinate with other NHS owners for data in the development of this TAMP. The following shows the extent of Montana's NHS systems.



Pavement and Bridge Data

MDT has dedicated offices for the collection and management of pavement and bridge data. MDT Pavement Management Section collects pavement condition annually for the state highway systems. Pavement data is managed in a dedicated pavement management system (PvMS). MDT's Bridge Management Section (BMS) inspects and collects bridge inventory data for Montana's bridges at scheduled intervals. The inventory includes all bridges and culverts that meet the definition of a bridge under National Bridge Inspection Standards (NBIS). Bridge data is managed in a dedicated structure management system (SMS).

Pavement and bridge data is used throughout the Department for project development, design, and investment processes. These management systems are data sources for required annual Federal reporting for the Highway Performance Monitoring System (HPMS) and National Bridge Inventory (NBI).

Current infrastructure condition is the baseline when considering an asset management approach. Montana’s current NHS asset condition is shown in the following table.

System	Inventory	% Condition**		
		Good	Fair	Poor
Interstate Pavements	4,700 lane miles	56.7%	41.6%	0.0%*
Non-Interstate NHS Pavements	6,505 lane miles	50.9%	48.3%	0.40%
NHS Bridge Deck Area	11,367,900 square feet	17.4%	75.3%	7.3%

*% Poor value lower than range

** Value less than 100% due to missing/under construction segments.

Performance Targets and State of Good Repair

To effectively track system condition performance over time, MDT established short-term performance targets and a long-term SOGR vision for the condition of Interstate and Non-Interstate NHS pavements and the condition of NHS bridges. MDT’s performance targets reflect state priorities established through public and stakeholder input provided during the development and implementation of TranPlanMT. MDT will use these performance targets to track and report progress for national performance management goals and consider these targets and SOGR when making investment decisions. MDT short-term performance targets and SOGR are shown in the following tables.

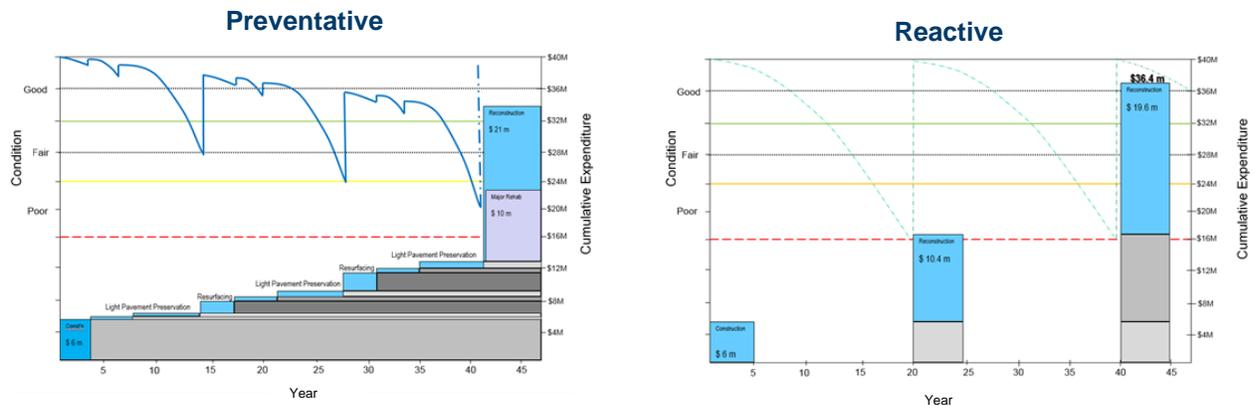
Performance Targets		
Asset	Good	Poor
Interstate Pavement	54%	3%
Non- Interstate NHS Pavement	44%	6%
NHS Bridge Deck Area	12%	9%

SOGR		
Pavement		
Interstate Pavement	80+	Ride Index
Non- Interstate NHS Pavement	76	Ride Index
Bridges		
NHS Bridge Deck Area	25%	Good
NHS Bridge Deck Area	3%	Poor

Life Cycle Planning

Knowing how to make the most effective investments is critical. Life Cycle Planning analysis considers the cost to manage an asset class from construction to replacement to help make effective investment decisions. Life cycle planning is the foundation of MDT's long-standing practice to employ the right treatment at the right time, since preserving existing assets costs much less than having to replace failing assets.

MDT's recommended pavement and bridge treatments in the TAMP are determined by using asset grouping and deterioration modeling to determine the lowest life cycle costs for the assets. The charts below demonstrate the cost/life span benefits of preserving assets rather than replacing them.



Performance Gaps and Strategies

With the right treatment model established, MDT identified gaps in performance by comparing current conditions and 10-year projected conditions versus the SOGR previously established, with the intent of determining strategies that could be implemented to close those gaps.

The current condition gap is a comparison of the SOGR versus the most recent data collected. The future gap considers current condition, resources available for future investment, projected system deterioration, planned investment by treatment type, competing needs, and potential risks, all resulting in likely future condition. The difference between the condition and the SOGR level results in system condition performance gaps. The NHS pavement and bridge SOGR gaps for 2017 and 2027 are as follows:

NHS Pavement Ride Index					
	SOGR Ride Index	Current Condition	Current Gap	Projected Condition (10-YR)	Projected Gap
Interstate Pavement	80+	82	0.0	80+	0.0
Non-Interstate NHS Pavement	76	72.6	3.4	76	0.0
NHS Bridge Deck Area					
	SOGR % Square Feet	Current Condition	Current Gap	Projected Condition (10-YR)	Projected Gap
Poor Condition	3%	7.3%	4.3%	3%	0.0
Good Condition	25%	17.4%	-7.6%	23%	2%

Though MDT has current performance gaps, the TAMP analysis projects that at the end of the 10-year period, pavement condition gaps will be eliminated. Bridge gaps will be significantly reduced. This is largely attributed to MDT already implementing strategies to maintain current condition or achieve progress toward closing these condition gaps.

MDT will continue to follow existing policy guidance to prioritize investments for NHS pavements and bridges. The Department anticipates achieving a desired SOGR on the NHS, assuming there are no broad changes in available resources.

In addition to condition related performance gaps, MDT also considered non-condition related issues that may negatively impact the performance of the Interstate and Non-Interstate NHS highways. This includes reoccurring congestion and non-reoccurring events.

Montana's relatively small population means reoccurring congestion is not a serious issue, while non-reoccurring events have a greater impact on mobility. To address non-reoccurring events, MDT has established practices for winter maintenance, construction work zone planning, traveler information systems, and preventing and addressing natural events and vehicle crashes.

Risk Management

MDT staff assessed the likelihood and consequence of risks or uncertainty that could affect Interstate and Non-Interstate NHS pavement and bridge conditions. The TAMP identifies the top three asset risks considering:

- ★ Uncertainty related to safety, mobility, asset damage, financial impact, and agency reputation;
- ★ Specific assets impacted;
- ★ Likelihood of occurring; and
- ★ Consequences.

MDT's top identified risks include: change in political climate; transportation funding being reduced by 20 percent in real dollars; and a freight-intensive market sector or unexpected development changing traffic volumes/patterns or negatively impacting infrastructure. Mitigation strategies are in place or have been identified to address these risks.

In addition to the risk assessment, MDT also performed a thorough review of past emergency events and determined there are no reoccurring repairs on the NHS. Issues at locations off the NHS have been identified, and mitigation measures are being planned or are underway.

Finances

The final asset management analysis before making investment decisions is to determine the sources and level of resources available. MDT's budget is a combination of state and Federal funding. Montana is heavily dependent on the Federal program with state funds limited to non-Federal match. Funding for NHS pavements and bridges generally comes from National Highway Performance Program (NHPP), National Highway Freight Program (NHFP), and State Highway Special Revenue (SHSR).

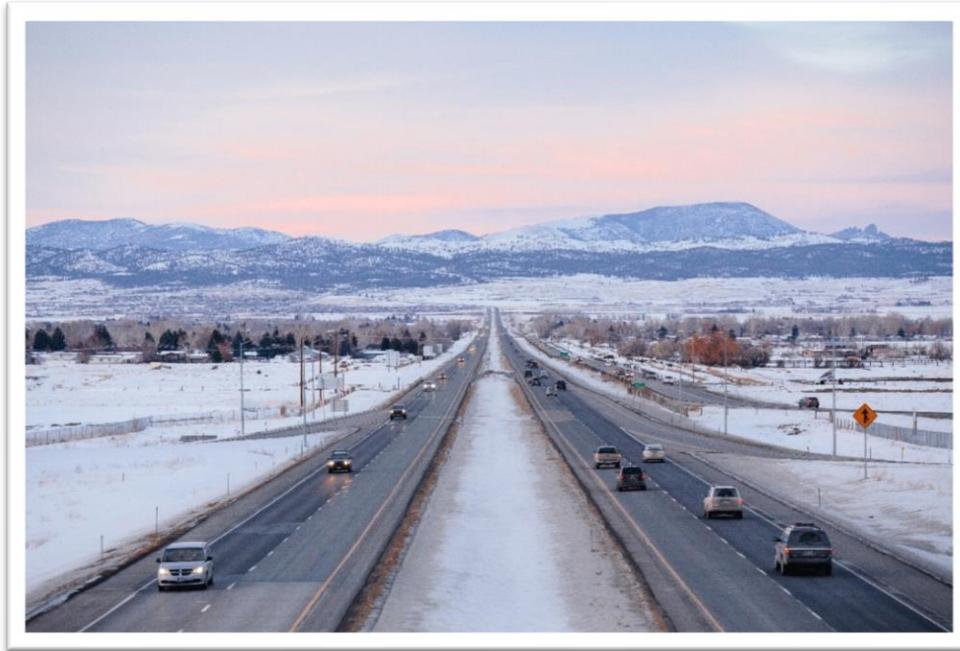
In 2017, MDT managed approximately \$762 million in total funding. Of this, \$456 million was directed to the Highway Construction Program. Federal funds for TAMP construction activities are expected to increase incrementally between 2018 – 2027 from \$38 million to \$46 million for Interstate pavement; \$71.2 million to \$108.3 million for Non-Interstate NHS pavement; and \$27.2 million to \$32.5 million for NHS bridges. MDT anticipates the value of Montana's NHS infrastructure will be maintained and system condition performance gaps will decrease, provided there are no changes in projected funding and MDT's focus remains on preservation.

Investment Strategies

MDT asset investment strategies were developed based on the preceding analysis considering short-term condition targets and long-range policy consistent with achieving or making progress toward the desired SOGR. The strategies supported by processes and data analysis consider life cycle planning, existing conditions, rates of deterioration, risks, and projected revenues to achieve the optimal investment with the available resources. MDT TAMP investment strategies are:

- ★ Right Treatment at the Right Time — focusing on preventative and rehabilitative efforts to cost effectively manage existing infrastructure and avoid expensive deferred maintenance.
- ★ Preservation — focusing on preserving and maintaining the existing infrastructure.
- ★ Targeted Assets — targeting certain asset categories for increased investment to address current condition deficiencies and to mitigate risks.

Through implementation of the TAMP, MDT is projected to meet performance targets and SOGR in support of the national performance goals established by MAP-21. MDT will continue long established business practices related to asset management, while aligning with new Federal requirements. MDT will reevaluate the TAMP as required along with reviewing performance targets in support of national goals. This will be accomplished while ensuring the Department fulfills its mission of providing a transportation system and services that emphasize quality, safety, cost effectiveness, economic vitality and sensitivity to the environment.



2 OVERVIEW

Actively managing transportation assets has been a fundamental business practice of the MDT for nearly 20 years. Since 1999, MDT has used the P3 (<http://www.mdt.mt.gov/pubinvolve/p3.shtml>) to develop an optimal, fiscally constrained highway funding plan and measure progress toward goals established in the Department's long-range transportation policy plan.

The plan, TranPlanMT (<http://www.mdt.mt.gov/tranplan/>), plus data about assets guides MDT's P3 in determining the best, system-wide mix of funding for resurfacing, rehabilitation, and reconstruction of the Montana highway system. This process annually evaluates investment alternatives through trade-off analysis to determine a cost-effective distribution of funds that achieves highway performance goals for pavement, bridge, congestion, and safety.

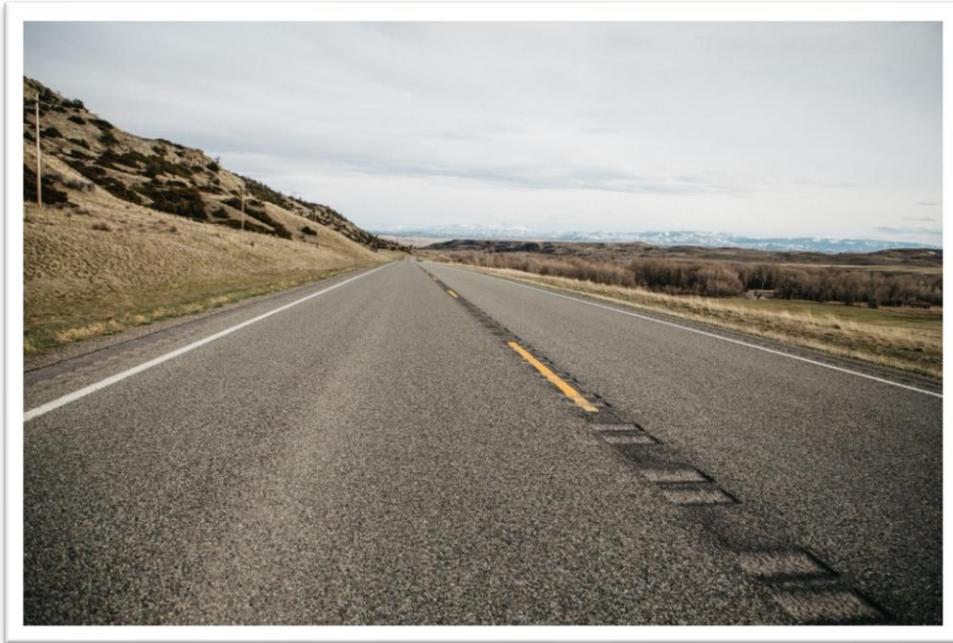
Through P3, MDT sets condition targets, tracks progress, and evaluates network level conditions for pavements and bridges to maintain consistent conditions across Montana. As part of P3, MDT allocates funds based on scenario analyses considering budget and work-type tradeoffs. These analyses are the foundation of the MDT asset management program.

Funding is distributed by district, highway system, and type of work. Then, specific projects are selected for the Statewide Transportation Improvement Program (STIP) (<http://www.mdt.mt.gov/pubinvolve/stip.shtml>).

MDT tracks the actual performance of the highway system after the investments are made to hone the predictive capacity of the management systems and MDT's overall accountability. Ride quality, traffic volume, bridge deck condition, and crashes are just a few of the many characteristics tracked.

The TAMP covers the period of 2018 – 2027 and builds on MDT’s 2015 TAMP. It describes how MDT manages pavements and bridges to fulfill the requirements of MAP-21. This risk-based asset management plan will help MDT achieve and sustain a SOGR over the life cycle of the assets and improve and preserve the condition of the NHS. The MDT TAMP achieves Federal compliance through describing MDT’s processes and approach for:

- ★ Collecting pavement and bridge data, ensuring data quality, and using management systems to analyze NHS bridge and pavement condition;
- ★ Determining performance targets and SOGR;
- ★ Life cycle planning;
- ★ Identifying performance gaps and activities and resources needed to close those gaps;
- ★ Assessing risks affecting NHS assets in Montana and manage these risks;
- ★ Developing a financial plan;
- ★ Identifying investment strategies that will help MDT achieve performance goals in a fiscally constrained environment; and
- ★ Identifying future enhancements in the MDT asset management framework.



3 SCOPE AND CONDITION

3.1 Overview

MDT manages, maintains, and collects all pavement and bridge data for the NHS in Montana. This includes all pavement and bridge condition data on the Interstate and Non-Interstate NHS. Asset condition data is the foundation for this TAMP and for MDT's long-standing asset management approach, P3. Inventory and condition data serve as the basis for MDT assessing current and future needs, improvement work type and timing, where and when to invest funds, also monitoring the performance and value of assets and improvement projects over time.

3.2 Federal Requirements

Through MAP-21, Congress directed states and the Federal Highway Administration (FHWA) to implement and transition to using asset management to drive state and Federal investment in the NHS. FHWA describes asset management as a strategic process for managing physical assets in an SOGR over their life cycle at minimum practicable cost.

In general terms, Federal requirements related to asset management are:

- ★ Ensuring the accuracy of the data by developing, documenting, and implementing procedures for collecting, storing, processing, and updating condition data;
- ★ Using data management systems to support asset inventory and management activities;
- ★ Developing risk-based asset management plans, including measures and targets for NHS pavement and bridge conditions;
- ★ Establishing an SOGR vision for the condition of NHS pavements and bridges;
- ★ Establishing 2- and 4-year condition targets for NHS pavement and bridge conditions that support achieving the state's SOGR that supports national goals;
- ★ Achieving no more than 5 percent of Interstate pavement lane miles in poor condition; and
- ★ Achieving no more than 10 percent structurally deficient (SD) NHS bridge deck area.

3.3 State Process

In addition to Federal requirements, P3 is used to allocate program funds for NHS pavements and bridges based on condition, deterioration models/life cycle treatments, and available resource. This is with consideration of investment needed in the individual asset categories (including but not limited to NHS pavements and bridges) to achieve MDT's overall system condition performance goals. Moving forward, MDT will conduct the P3 analysis with consideration of the TAMP and national performance requirements to ensure MDT continues to meet Montana's infrastructure needs while making investment decisions consistent with the TAMP and the national performance goals for Interstate pavements, Non-Interstate NHS pavements, and NHS bridge deck area.

3.4 TAMP Scope and System Summary

This TAMP includes NHS pavements and bridges, MDT's most extensive assets in terms of cost and extent. All of the pavement and bridge data in the TAMP is based on the 2018 HPMS and NBI data submittals. The Montana state highway system is comprised of many other assets, however existing processes will continue to be relied on for their management, rather than including them in this TAMP. Figure 3-1 shows the Montana NHS, and Table 3-1 provides an inventory and condition summary of the NHS.

Figure 3-1 Montana NHS

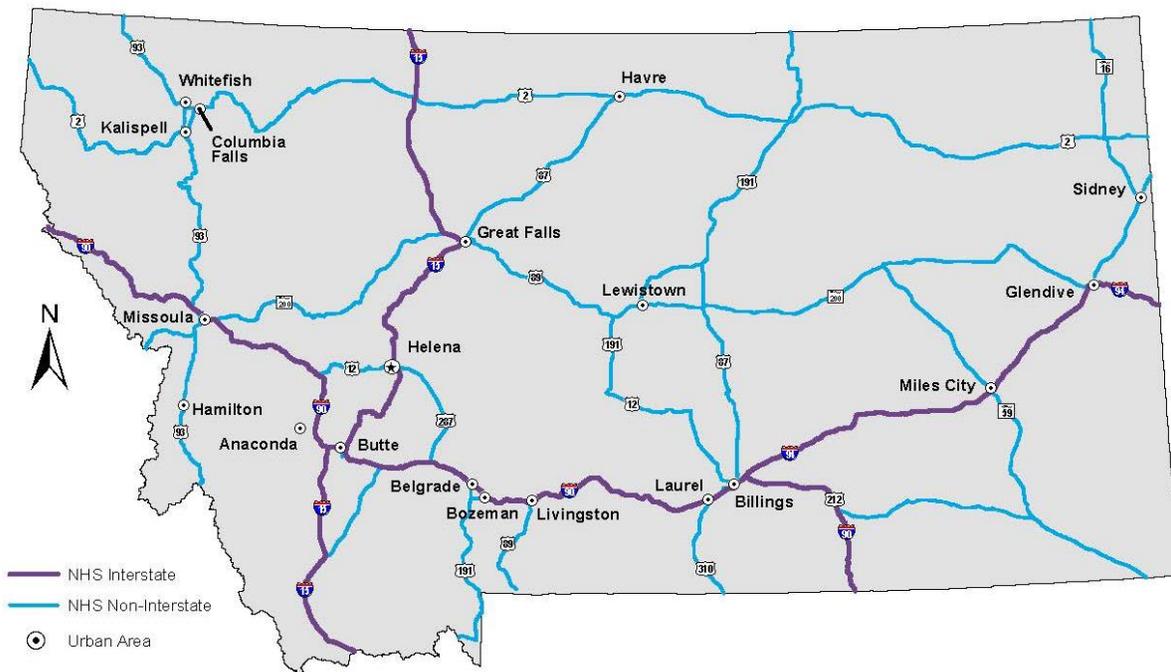


Table 3-1 Montana NHS Inventory and Condition

System	Inventory	% Condition**		
		Good	Fair	Poor
Interstate Pavements	4,700 lane miles	56.7%	41.6%	0.0%*
Non-Interstate NHS Pavements	6,505 lane miles	50.9%	48.3%	0.40%
NHS Bridge Deck Area	11,367,900 square feet	17.4%	75.3%	7.3%

*% Poor value lower than range

** Value less than 100% due to missing/under construction segments.

3.5 Managing Pavement

Pavements are designed to support anticipated traffic loads and provide a safe and relatively smooth driving surface. Keeping pavements in good condition lengthens their life, enhances safety, and helps reduce road user operating costs. MDT strives to achieve the right treatment at the right time to make the most of limited funding. Resurfacing and rehabilitation projects can extend the life of the asset and delay the need for reconstruction. For every dollar spent on timely preventative maintenance, \$4 to \$8 will be saved from complete reconstruction in the near term.

The MDT Pavement Program directly supports the statewide goals established by TranPlanMT. MDT continues to implement the following activities and actions in support of strategic statewide goals:

- ★ **Preservation of the existing system** — providing the “right treatment at the right time” to actively manage pavements using cost-effective treatments. Activities include crack seal, seal and cover, rut fill, mill/fill, overlay, micro-surfacing, cold-in-place recycle, and hot-in-place recycle treatments.
- ★ **Capacity expansion and mobility improvements** — improving the roadway network when the current roadway can no longer support continued growth using current geometrics. Activities include major rehabilitation and reconstruction treatments to address level-of-service deficiencies by adding lanes and/or shoulder width.
- ★ **Safety and other improvements** — maintaining pavement condition to ensure safety for the traveling public. Activities related to safety include rut-fill, chip seal, and concrete diamond grind.

3.5.1 Pavement Inventory

There are approximately 75,000 center lane miles open to public travel in Montana with over 12 billion vehicle miles travelled annually. More than half the miles travelled occur on just nine percent of the roadway system – the Interstate and Non-Interstate-NHS road networks.

3.5.2 Measuring Pavement Conditions

Monitoring and measuring pavement condition help MDT assess the performance of the transportation system, predict future needs, allocate funding, and schedule projects.

MDT collects pavement condition data annually with automated data collection vehicles (ADCV). The ADCVs use high definition images and lasers to measure pavement condition every 0.1 mile of the Montana highway system.

Pavement condition data is managed in the MDT PvMS. Pavement conditions are monitored using metrics from analyzed data calculated on a scale of 0 to 100. Annually, pavement data is reported to the HPMS, FHWA's national database for highways. MDT uses the following metrics for evaluating pavement condition:

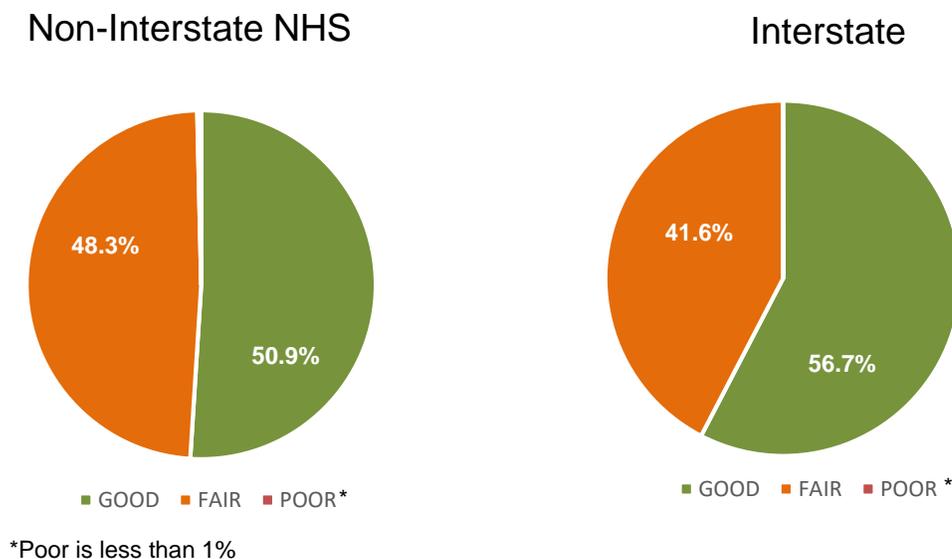
- ★ **Ride Index (RI)** — A measure of traveler perception of ride smoothness. RI is based on the International Roughness Index (IRI), the international standard for smoothness. MDT assigns Good, Fair, Poor categories on a scale of 0 to 100 (with lower numbers being associated with Poor condition and higher numbers being associated with Good condition).
- ★ **Rut Index** — A measure of rut depth along the wheel path.
- ★ **Cracking**
 - Alligator Crack Index (ACI) — a measure of the amount of cracking caused by traffic loading (fatigue cracking)
 - Miscellaneous Crack Index (MCI) — a measure of the amount of non-load cracking (longitudinal/transverse cracking for asphalt, slab cracking for concrete)
 - Faulting — adjacent concrete pavement slab misalignment

MDT uses RI as the performance measure for pavements in P3 as an indicator of pavement condition.

3.5.3 Pavement Condition Trends

MDT implements P3 optimized investment plans, then measures progress towards statewide goals. Through P3, MDT establishes Ride targets, tracks progress, and evaluates network level pavement Ride performance to maintain consistent performance throughout the state. Figure 3-2 shows the NHS pavement condition.

Figure 3-2 NHS Pavement Condition by Lane Miles



3.6 Managing Bridges

The MDT Bridge Program supports the goals established in TranPlanMT by emphasizing work that prioritizes:

- ★ **Preservation of the existing system** — providing the “right treatment at the right time” to manage bridges using cost-effective treatments. Activities include bridge deck preservation and rehabilitation, corrosion mitigation, joint repair or replacement, and bridge rail upgrades.
- ★ **Safety** — maintaining bridge conditions to ensure safety for the traveling public. Activities related to traffic safety range from simple skid treatments to full replacements or new alignments. Other activities cover seismic retrofitting of vulnerable bridges and installation of scour countermeasures on susceptible bridges.
- ★ **Efficient business decisions** — analyzing investment strategies to maximize system performance (given limited state and Federal resources). Activities include management system upgrades and business process improvements that promote effectiveness and efficiency.
- ★ **Mobility and economic vitality** — improving the roadway network when the current roadway can no longer support continued growth using current geometrics. Activities include full replacements on new alignments with increased traffic capacity.

3.6.1 Bridge Inventory

MDT inspects the status and condition of Montana bridges at regularly scheduled intervals and reports to FHWA annually. This reporting includes inventory and inspection data for bridges and culverts located on the NHS that meet the definition of a bridge under NBIS. In March 2018, MDT reported 4,172 bridges and 299 culverts throughout the state that meet these criteria. Table 3-2 shows a breakdown of the NHS bridge inventory that includes 1,228 bridges (29 percent of statewide total) and 117 culverts (39 percent of the statewide total). Unless specified otherwise, bridges as referenced in this TAMP include culverts that meet the definition of a bridge under NBIS.

Table 3-2 NHS Bridges and Culverts in Montana

System	Bridges (#)	Bridge Deck Area (ft ²)	Culverts (#)	Culvert Deck Area (ft ²)
Interstate	786	7,156,349	31	84,262
Non-Interstate NHS	442	4,023,031	86	104,258
All NHS	1,228	11,179,380	117	188,520

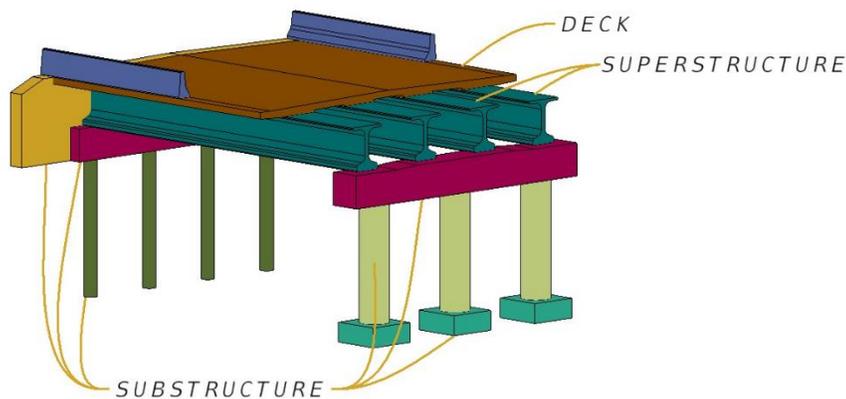
3.6.2 Measuring Bridge Condition

MDT performs full NBI and National Bridge Element (NBE) inspections on most bridges every two years with some bridges on differing cycles depending on condition and bridge type. MDT bridge staff has developed maintenance inspection procedures that maintenance personnel use to conduct routine maintenance inspections every six months to identify emerging issues.

MDT's BMS is responsible for the overall bridge inspection program including primary responsibility for database management, the inspection data Quality Assurance/Quality Control (QA/QC) program, and program quality assurance. BMS assists in updating the performance measures of structure and deck condition to determine whether proposed projects will meet program objectives. MDT's Bridge Inspection and Rating Manual describes program organization and function (Article 1.3.1) and QA/QC (Article 2.2.17).

Figure 3-3 shows the major bridge components that are individually inspected and rated. These components include: the deck, including the surface vehicles drive on; the superstructure supporting the deck; and the substructure that transfers the load of the bridge to the ground.

Figure 3-3 Major Components of Bridge Inspection



Bridge condition ratings are used to classify a bridge as being in Good, Fair, or Poor condition. The lowest of the three ratings for deck, superstructure, and substructure determines the overall rating for the bridge. If this value is 7 or greater, the bridge is classified as being in Good condition. If it is 5 or 6, the bridge is classified as being in Fair condition. If it is 4 or less, the bridge is classified as being in Poor condition. If any major component is classified as being in Poor condition, the bridge is considered SD. This designation does not indicate that a bridge is unsafe. Rather, it indicates deficiencies exist that require maintenance work, rehabilitation activities, or replacement of the structure.

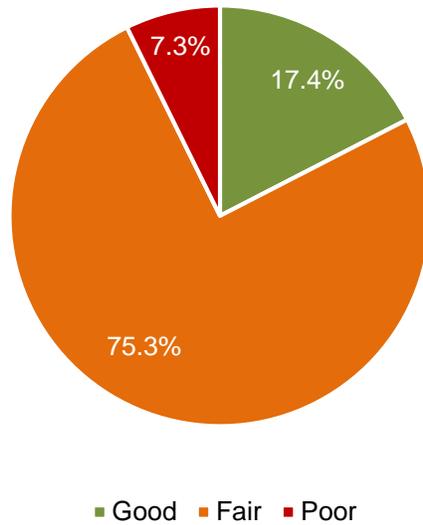
For culverts, a single rating of 0 to 9 is assigned for the entire structure. The numerical values for Good, Fair, and Poor culverts correspond to those for bridges as shown in Figure 3-4.

Figure 3-4 Bridge Condition Rating

NBI Ratings									
9	8	7	6	5	4	3	2	1	0
Good			Fair		Poor				

Figure 3-5 shows the percentage of Good, Fair, Poor NHS bridges by deck area.

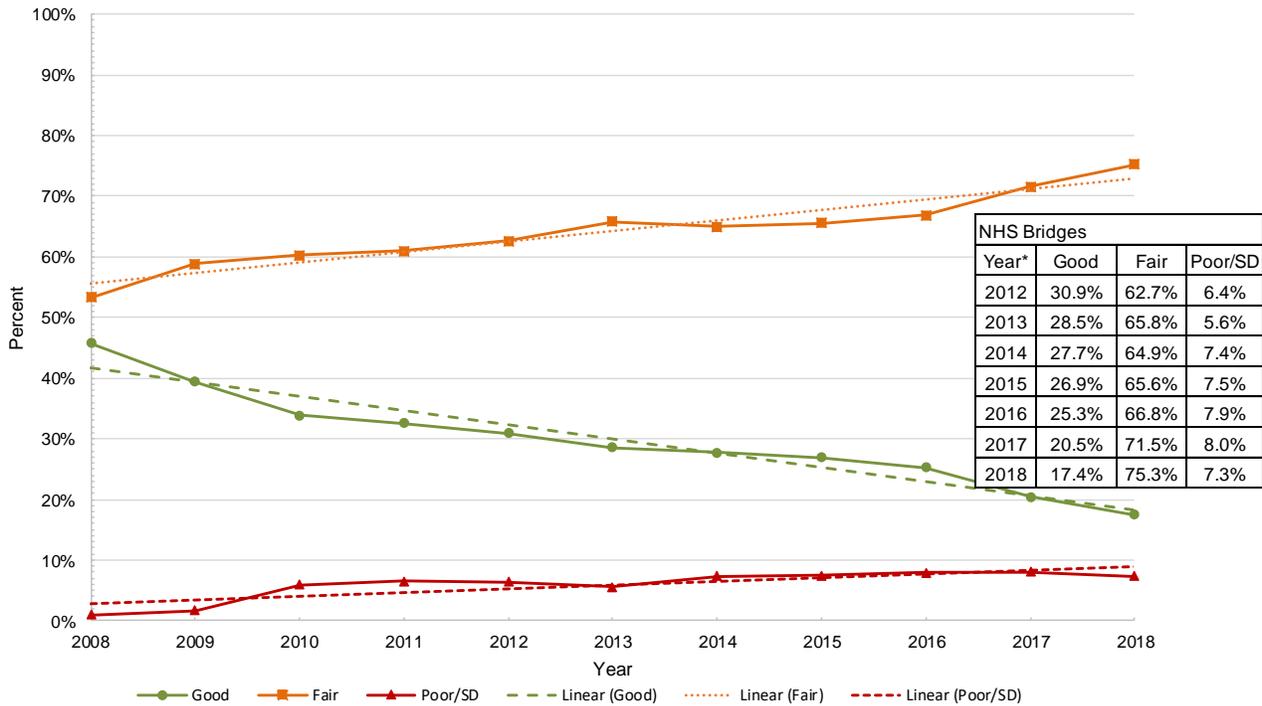
Figure 3-5 NHS Bridges by Condition Weighted by Deck Area



3.6.3 Bridge Condition Trends

In recent years, bridge and culvert conditions have deteriorated across the state. On the NHS, the percentage of Poor (SD) bridges and culverts by deck area is stabilizing while the percentage of Good bridges and culverts by deck area continues to decline, with a corresponding increase in the percentage of Fair bridges and culverts. Figure 3-6 illustrates these trends.

Figure 3-6 NHS Bridge Deck Area Condition Trends

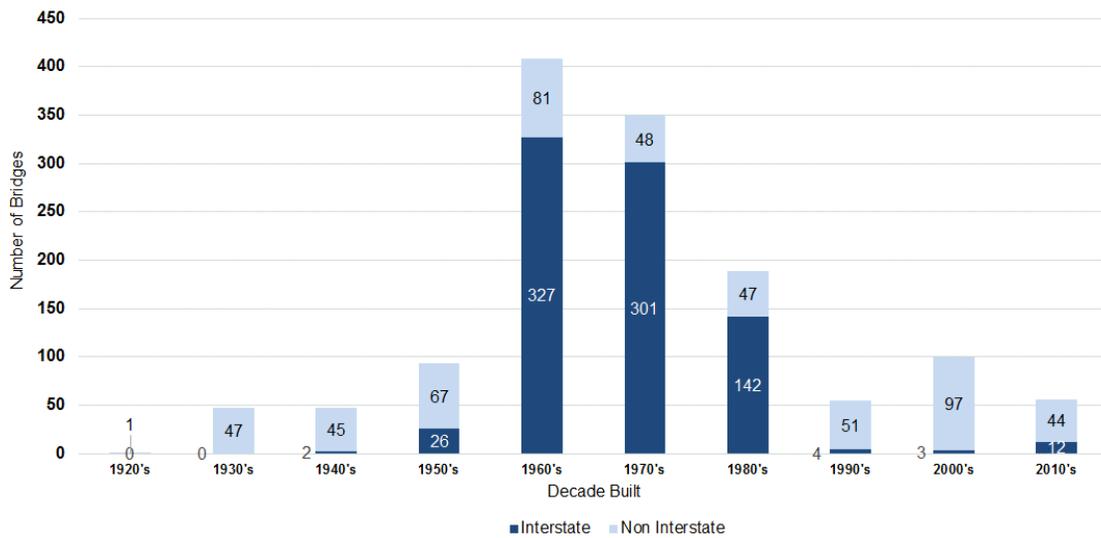


*NBI submittal year: 2018 NBI submission date = 2017 year-end condition data

While many factors are contributing to this decline, the primary contributor is the age of Montana NHS bridges. The majority of these bridges were built with the Interstate system as shown in Figure 3-7. Additionally, Montana’s harsh environment makes construction and maintenance of bridge decks challenging.

MDT is making progress toward reversing these trends. Major program changes were initiated in response to the requirements of MAP-21 and the Fixing America’s Surface Transportation Act (FAST Act). MDT substantially increased Bridge program allocations. Additionally, MDT has implemented cost-effective preservation and rehabilitation strategies to address degradation of bridge elements, primarily decks. As noted previously, these changes have helped stabilize the percentage of Poor bridges and will help reduce the rate of decline for Good bridges in the future.

Figure 3-7 Number of NHS Bridges by Year Built



4 PERFORMANCE TARGETS AND STATE OF GOOD REPAIR

Performance targets specifically identify pavement and bridge conditions that MDT seeks to achieve and sustain for the foreseeable future to support the Department’s goals and objectives and to meet Federal requirements for NHS pavements and bridges.

Montana targets reflect the state priorities established through public and stakeholder input provided during the development and implementation of TranPlanMT, Montana Freight Plan (<http://www.mdt.mt.gov/freightplan/default.shtml>), and Montana Comprehensive Highway Safety Plan (CHSP) (<http://www.mdt.mt.gov/visionzero/plans/chsp.shtml>).

Target setting is guided by system condition data, deterioration and optimization models, resource projections, and consideration of competing needs. The 2- and 4-year targets are aligned with MDT strategic planning goals and will be used to direct decisions to support achieving the longer term SOGR.

MDT targets and SOGR were established by the MDT TAMP Steering Committee based on recommendations provided by working groups that were formed for each of the national performance areas. These working groups evaluated existing conditions, past performance, management system outputs, available resources, and policy and public input to develop target options. The processes and options were discussed with Montana Metropolitan Planning Organizations (MPO) for their input prior to being presented to the TAMP Steering Committee.

The Steering Committee established the performance targets and SOGR shown in tables 4-1 and 4-2 for Montana NHS pavements and bridges.

Table 4-1 NHS Pavement and Bridge Performance Targets

Asset	Good	Poor
Interstate Pavement	54%	3%
Non-Interstate NHS Pavement	44%	6%
NHS Bridge Deck Area	12%	9%

Table 4-2 State of Good Repair

Pavement		
Interstate Pavement	80+	Ride Index
Non-Interstate NHS Pavement	76	Ride Index
Bridges		
NHS Bridge Deck Area	25%	Good
NHS Bridge Deck Area	3%	Poor

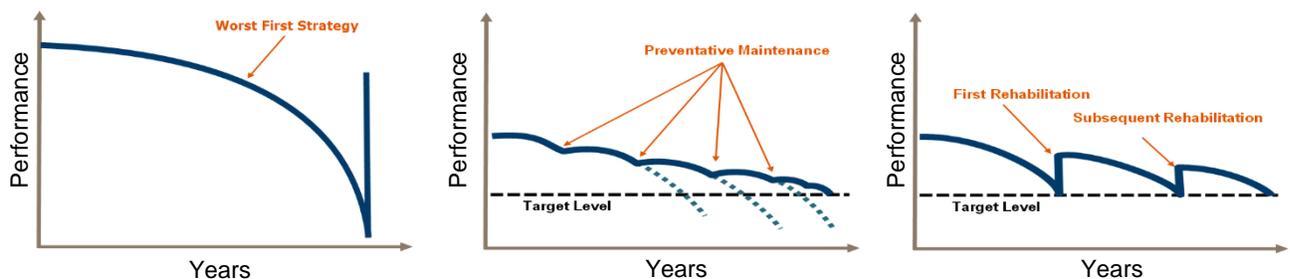


5 LIFE CYCLE PLANNING

FHWA defines life cycle cost as the cost of managing an asset class or asset sub-group for its whole life, from initial construction to replacement. A life cycle plan (LCP) is a strategy for managing an asset over its life to achieve a target level of performance while minimizing life cycle costs. LCP focuses on network-level asset management strategies that represent the most cost-effective sequence of maintenance, preservation, and rehabilitation treatments for a given asset.

Life cycle cost analysis (LCCA) is a technique for comparing cost alternatives over the life cycle of a project. LCCA is used for project level decisions to select the design option that minimizes the initial and discounted future costs over an analysis time period. The basic principle underlying both LCP and LCCA is fundamental to asset management: timely investments in an asset can result in improved condition and lower long-term cost. This principle is illustrated in Figure 5-1 depicting condition and costs over time.

Figure 5-1 Life Cycle Cost Considerations



MDT's life cycle planning processes are intended to maximize asset condition while minimizing cost through a systematic process of making investment and treatment decisions. These processes are based on the Department's strategic goals, with consideration of constraints and tradeoffs needed to achieve and sustain MDT's 2- and 4-year performance targets and SOGR.

5.1 Pavement Life Cycle Planning

The overall life cycle of pavement begins in policies established by the Department. After construction, the condition is assessed annually through the cycle of treatments to the end of the pavement useful life when reconstruction may occur. The following figures show two example scenarios of pavement life cycle planning. Figure 5-2 is an asset management approach of proactive maintenance. Figure 5-3 is a costlier reactive approach.

Figure 5-2 Proactive Pavement Management Strategies

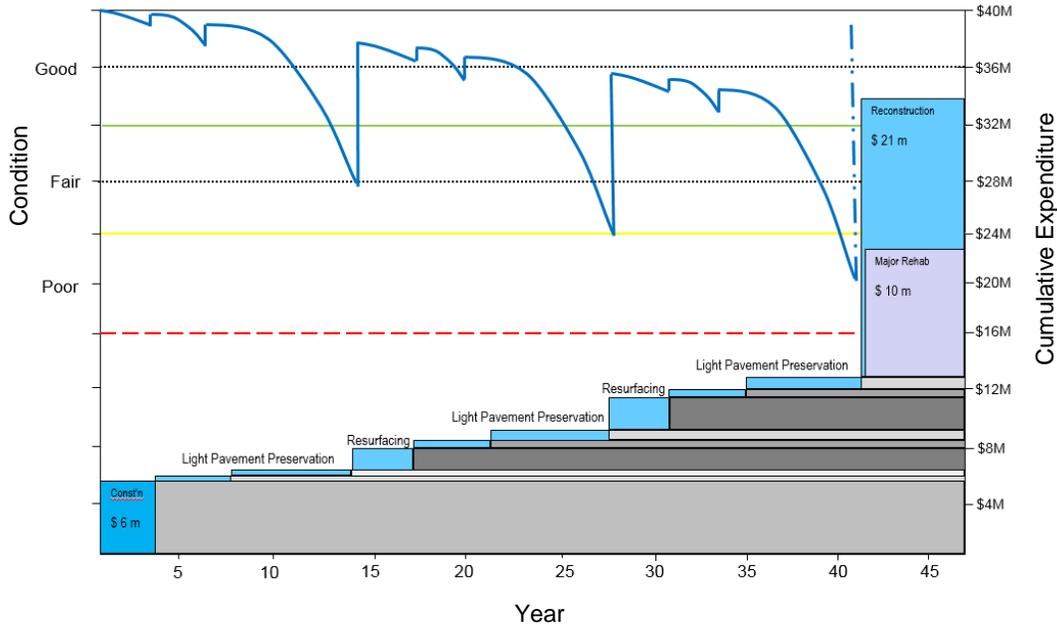
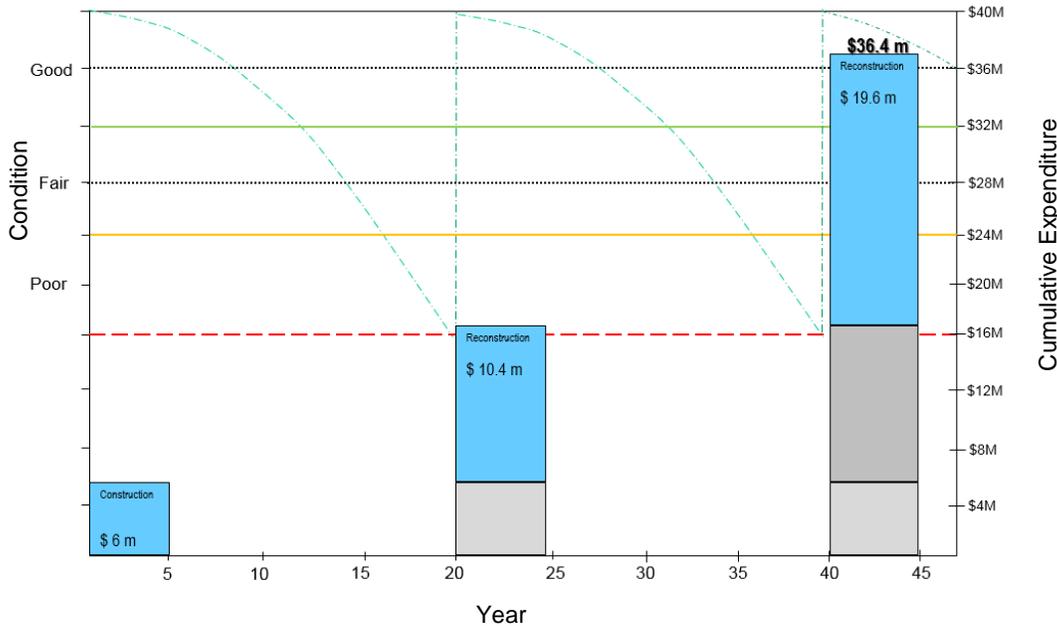


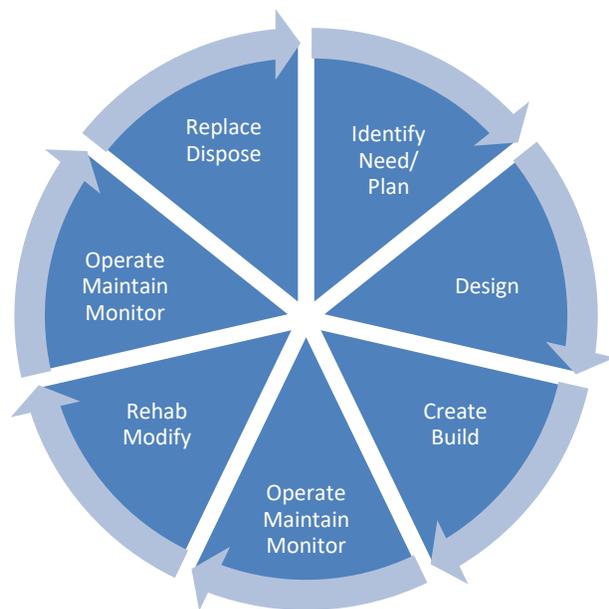
Figure 5-3 Reactive Pavement Management Strategies



MDT monitors and analyzes the life cycle of pavement assets in four categories including Interstate, Non-Interstate NHS, Primary, and Secondary roadways. The life cycle of pavements is shown in Figure 5-4.

Figure 5-4 Pavement Life Cycle

5.1.1 Pavement Data Collection



- ★ The cycle begins or renews with identifying the need and planning for new construction or reconstruction.
- ★ The design phase encompasses developing the right-of-way, safety, and geometrics for the given roadway.
- ★ As the pavement ages after construction/reconstruction, MDT addresses pavement distresses with pavement preservation strategies, rehabilitation treatments, and maintenance for managing an overall cost-effective life cycle.

The MDT Pavement Management Unit collects pavement data with ADCVs including: IRI, rutting, alligator cracking, and miscellaneous cracking on asphalt pavements. On concrete pavements, MDT collects IRI, rutting, slab cracking, and faulting. PvMS converts the raw measurements into distress (IRI, rut, and cracking) indices correlating to decision trees that determine treatments for each distress.

5.1.2 Pavement Modeling Approach

Data collected with the ADCVs are used in PvMS to model pavement deterioration and prioritize pavement treatments. Deterioration curves are based on statistical analysis of historical condition data by system and most recent treatment type. With PvMS, MDT analyzes and predicts needs for each pavement segment based on its unique conditions and evaluates funding scenarios to determine the lowest life cycle cost. PvMS supports decision making based on a project optimization tool using pavement condition, pavement type, previous project history, and traffic level to propose the right treatment at the right time. PvMS allows MDT to model deterioration scenarios for each pavement segment depending on these variables and identifies the needs of each highway segment.

MDT pavement condition modeling includes assumptions about treatments, their impacts on condition, and their costs. Unit costs for treatments are based on an average of costs from construction and maintenance projects including material, traffic control, mobilization, and more.

5.1.3 Pavement Strategies

Decision trees are configured by system and distress index. The treatments, as shown in Figure 5-5, increase in complexity as the pavement deteriorates. The recommended treatments are options considered by MDT District staff during project nomination. MDT Headquarters and District staff work together through the design phase to further define the cost-effective scope of work to address the observed distress and roadway features.

Figure 5-5 MDT Pavement Treatments

Maintenance	Preservation	Rehabilitation
<ul style="list-style-type: none"> • Patching • Crack seal/joint seal • Fog seal • Seal and cover • Scrub seal • Rut filling 	<ul style="list-style-type: none"> • Crack seal/joint seal • Fog seal • Seal and cover • Sand seal • Scrub seal • Concrete panel repair/replacement • Dowel bar retrofit • Diamond grinding • Cape seal • Mill/fill • HIR • CIR • White topping 	<ul style="list-style-type: none"> • Crack and seat with overlay • 0.2 ft ≤ overlay • 0.2 ft ≤ mill & overlay ≤ 0.3 ft • CIR < 0.4 ft with overlay ≤ 0.3 ft • CCPR with overlay • Complete concrete treatment: DBR, diamond grind, joint seal, slab replacement, bituminous overlay • Full depth reclamation • Pulverize with overlay

5.1.4 Pavement Treatments

MDT’s approach to treatment selection incorporates the cost effectiveness of each treatment in the pavement life cycle shown in Table 5-1. MDT addresses routine maintenance through light pavement preservation treatments. These include crack sealing and chip sealing, which may be applied multiple times after construction and between resurfacing projects.

Table 5-1 Pavement Treatment Cost Effectiveness (2017)

Scope	Treatment	Cost per lane mile	Years Gained per lane mile	Annual Cost per lane mile
Light Preservation	Crack Seal	\$4,600	3	\$1,500
	Chip Seal	\$21,000	7	\$3,000
Resurfacing	Microsurface	\$56,300	7	\$8,000
	Overlay	\$116,700	12	\$9,700
	Minor Rehab	\$140,300	12	\$11,700
Structural/ Capacity/ Geometric	Major Rehab	\$291,600	15	\$19,400
	Reconstruction	\$631,800	20	\$31,600

PvMS recommends treatments based on a series of decision tree considerations by MDT engineering staff to use in minimizing pavement life cycle costs. MDT also conducts detailed life cycle cost analysis for major rehabilitation and reconstruction projects. As part of this analysis, design staff evaluate multiple design alternatives and estimate the cost of future activities over a life cycle of 40 years or more. The goal of this process is to select a design alternative that leads to the lowest life cycle cost, even though this may not be the lowest initial construction cost.

MDT’s guidelines for nomination and development of roadway projects identifies the business and development rules for pavement projects. All surfacing treatments include a chip seal with the project. Pavement preservation treatments of crack seal and chip seal follow a surfacing project. Generally, three

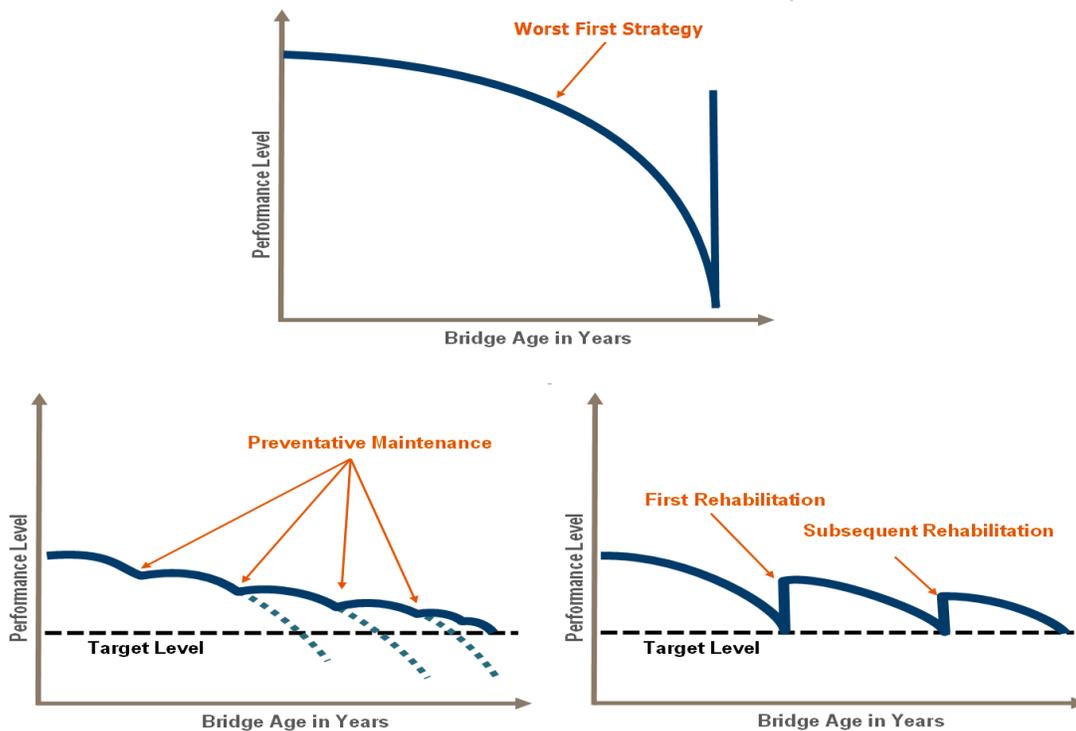
years later the surface will be crack sealed, followed by a chip seal between years seven and ten. The complexity of the resurfacing project depends on the condition and geometrics, but usually the initial resurfacing in the cycle is an overlay.

Each treatment type is assigned a priority within PvMS. Crack seal and chip seal have the lowest priority. The priorities progressively increase with the level of scope of work with reconstruction assigned the highest priority. As PvMS works through the indices, associated curves, and decision trees, the treatment with the highest priority for the given pavement segment is recommended.

5.2 Bridge Life Cycle Planning

Life cycle planning strategies that emphasize preservation activities are generally more cost-effective and maintain asset conditions at a higher performance level over time than rehabilitation or worst first strategies. Figure 5-6 illustrates the life cycle profiles for three different bridge investment strategies. The top graph shows the worst first strategy. The bottom left graph shows a life cycle planning strategy that emphasizes preservation. The bottom right graph represents a strategy that promotes rehabilitation treatments with minimal preservation activities.

Figure 5-6 Bridge Life Cycle Investment Strategies



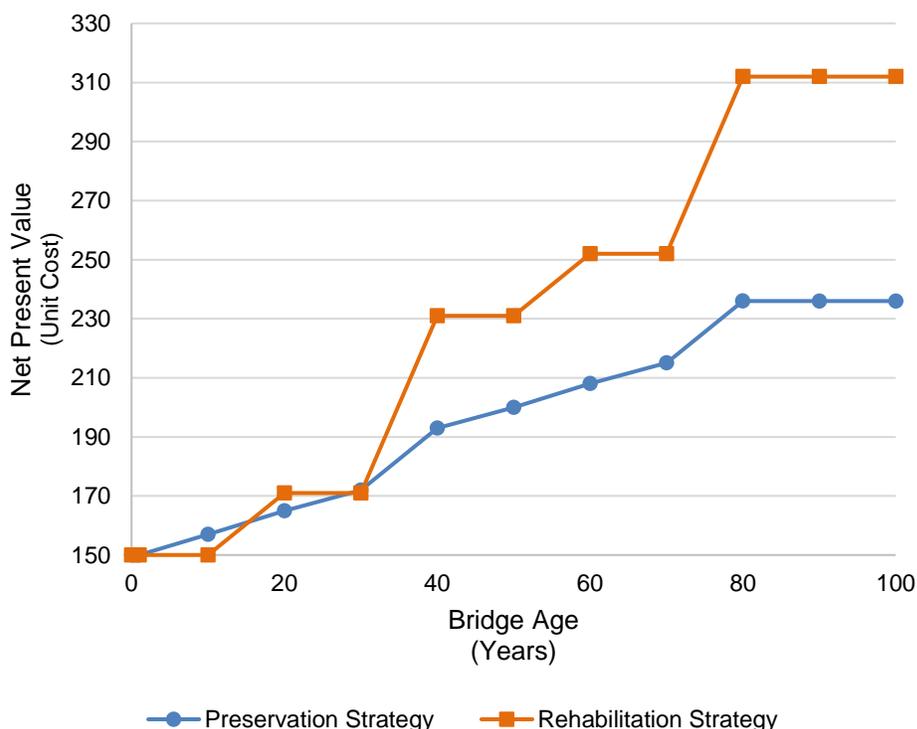
The treatments increase in complexity as bridge condition deteriorates. The recommended treatments shown in Figure 5-7 are some options considered for preventative maintenance, preservation, and rehabilitation of bridges.

Figure 5-7 Bridge Treatments

Maintenance	Preservation	Rehabilitation
<ul style="list-style-type: none"> • Debris Removal • Drain system cleanout • Patch and reseal joints • Repair minor damage to members 	<ul style="list-style-type: none"> • Concrete surface coatings and sealants • Shallow concrete patches • Spot painting steel • Thin deck overlays • Joint seal replacement 	<ul style="list-style-type: none"> • Deck milling and thick concrete overlay • Deck replacement • Joint replacement • Girder repair • Timber pile and cap repair • Reset or replace bearings

MDT’s approach to treatment selection incorporates the cost effectiveness of each treatment in the bridge life cycle. Figure 5-8 shows rehabilitation versus preservation condition-based on life cycle planning strategies.

Figure 5-8 Bridge Condition-Based Life Cycle Planning Strategies



5.2.1 Bridge Data Collection

To evaluate the effectiveness of life cycle planning alternatives, MDT must obtain and maintain the best possible information on its bridges.

As mentioned previously, MDT performs full NBI and NBE inspections on most bridges every two years, with some bridges on differing cycles depending on condition and bridge type. The inspection cycles are completed by qualified bridge inspection team leaders and are consistent with the requirements of the NBI program. MDT maintenance personnel also conduct routine maintenance inspections between the standard Federal inspection cycle to identify emerging issues.

During a routine inspection, a certified bridge inspector is responsible for performing element level inspections on all structural members of the deck, superstructure, and substructure. The conditions of the structural members are documented following the guidelines provided in MDT's bridge manual.

All data collected during the inspection process is documented and maintained in the MDT Structure Management System. The data is compiled and submitted annually to FHWA according to the Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges, Report No. FHWA-PD-96-001.

Bridge inspection staff receive ongoing training to provide consistent information on the best practices to address condition defects found during the inspection process. The results of each bridge inspection are documented in a formal Bridge Inspection Report that is electronically signed and stored in the Structure Management System.

5.2.2 Bridge Modeling Approach

Information contained in the Structure Management System is the primary driver for models utilized to predict future performance for Montana bridges. By monitoring bridge conditions over time, it is possible to establish deterioration curves and expected benefits for various bridge treatment options. Treatment options are then evaluated versus costs to establish benefit-cost ratios. The grouping of treatment options that optimizes performance over time compared to other alternatives represents the preferred life cycle plan.

For NHS bridges, MDT has conducted statistical analysis on historical data to establish degradation curves and expected benefits for the majority of NHS bridge treatment options. In most cases, MDT has sufficient historical data to develop reasonable deterioration and performance models. Because the modeling process is dynamic, MDT is constantly refining models based on the latest inventory data, input from engineers, information from research efforts, and guidance from industry experts.

MDT's Bridge Management program has acquired licenses for the National Bridge Investment Analysis System (NBIAS) software which was developed by Spy Pond Partners LLC for the FHWA to support the creation of a national bridge investment strategy. NBIAS is a powerful modeling tool that predicts bridge preservation, improvement, and replacement needs and forecasts bridge performance measures for various budget levels and operating assumptions. MDT bridge staff have begun product testing using bridge condition data imported from SMS. NBIAS will be MDT's primary predictive modeling tool while further research and refinement of Montana specific deterioration models and tools are developed.

5.2.3 Bridge Strategies

MDT deterioration curves, performance models, and treatment costs help determine the cost-effectiveness of various bridge treatment strategies. Table 5-2 shows two life cycle planning strategies for a bridge through its anticipated life. The first strategy promotes rehabilitation treatments with minimal preservation activities. The second strategy emphasizes preservation treatments. Although both strategies are effective, MDT will benefit from pursuing a life cycle plan that emphasizes preservation activities.

Table 5-2 Rehabilitation Versus Preservation Life Cycle Planning Costs

Rehabilitation			Preservation		
Activity	Year	Cost (ft ²)	Activity	Year	Cost (ft ²)
New Construction	0	\$150	New Construction	0	\$150
Deck Rehabilitation	20	\$20	Preservation Treatment	10	\$7
Joint Replacement		\$1	Preservation Treatment	20	\$7
Deck Replacement	40	\$60	Joint Replacement		
Deck Rehabilitation (Mill & Thick Overlay)	60	\$20	Preservation Treatment	30	\$7
Joint Replacement		\$1	Deck Rehabilitation (Mill & Thick Overlay)	40	\$20
Deck Replacement	80	\$60	Joint Replacement		
Replace Bridge	100		Preservation Treatment	50	\$7
Net Present Value		\$312	Preservation Treatment	60	\$7
			Joint Replacement		
			Preservation Treatment	70	\$7
			Deck Rehabilitation	80	\$20
			Joint Replacement		
			Replace Bridge	100	
			Net Present Value		\$236

Examples of management strategies MDT will consider implementing for a preservation focused lifecycle management plan may include:

- ★ After new construction, deck replacement, or rehabilitation, perform a preservation treatment within the first 10-years of service.
- ★ After the initial preservation treatment, continue to apply preservation treatments at about 10-year intervals, based on individual bridge type life cycle and actual condition needs, until a deck rehabilitation or replacement treatment is necessary.
- ★ Continue to monitor substructure and superstructure conditions to assess whether bridge replacement is the preferred treatment alternative.

In addition, MDT may consider additional preservation treatments during the life cycle; when opportunities exist and the bridge condition warrants additional work. These opportunities may include:

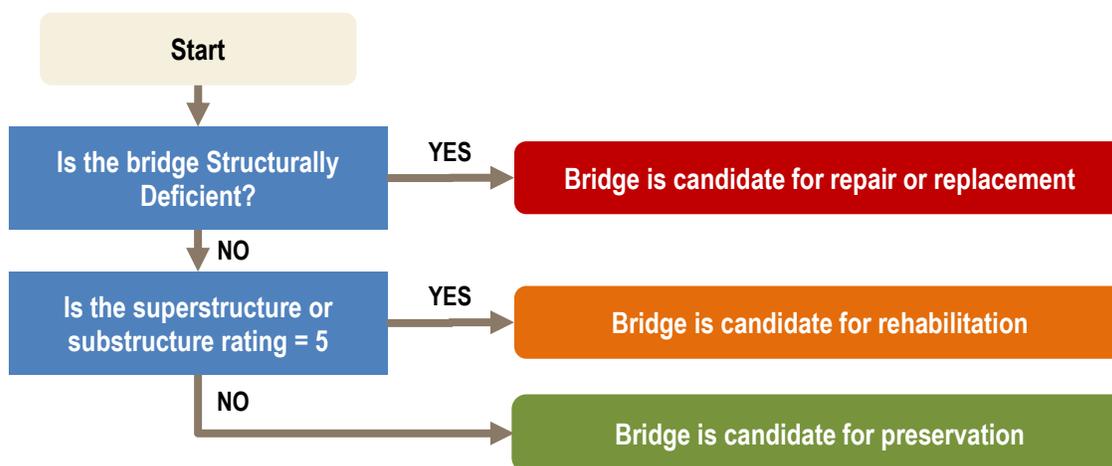
- ★ Consider performing bridge treatments such as thin overlays with MDT pavement preservation projects to capitalize on mobilization and traffic control already in place.
- ★ Install thin overlays early in the bridge lifecycle.
- ★ Consider alternative contracting methods such as Job Order Contracts to strategically address specific bridge maintenance and preservation needs.
- ★ Consider partnering with MDT Districts to advance Interstate and NHS projects that improve bridge conditions.
- ★ Consider partnerships with the Highway Safety Improvement Program (HSIP) to advance safety projects that also improve bridge conditions.
- ★ Consider utilizing NHFP funding for bridge projects as bridge reliability was identified as a high priority in the Montana Freight Plan.

The lifecycle treatments described here represent preservation strategies for new or newly rehabilitated structures. Existing bridges are at various stages of condition which may require alternative rehabilitation strategies and preventative maintenance to optimize performance over the anticipated remaining life.

5.2.4 Bridge Treatments

MDT applies a series of decision trees when selecting bridge preservation, repair, and rehabilitation treatments. MDT determines the candidate treatments for superstructure and substructure condition using the bridge improvement decision process illustrated in Figure 5-9.

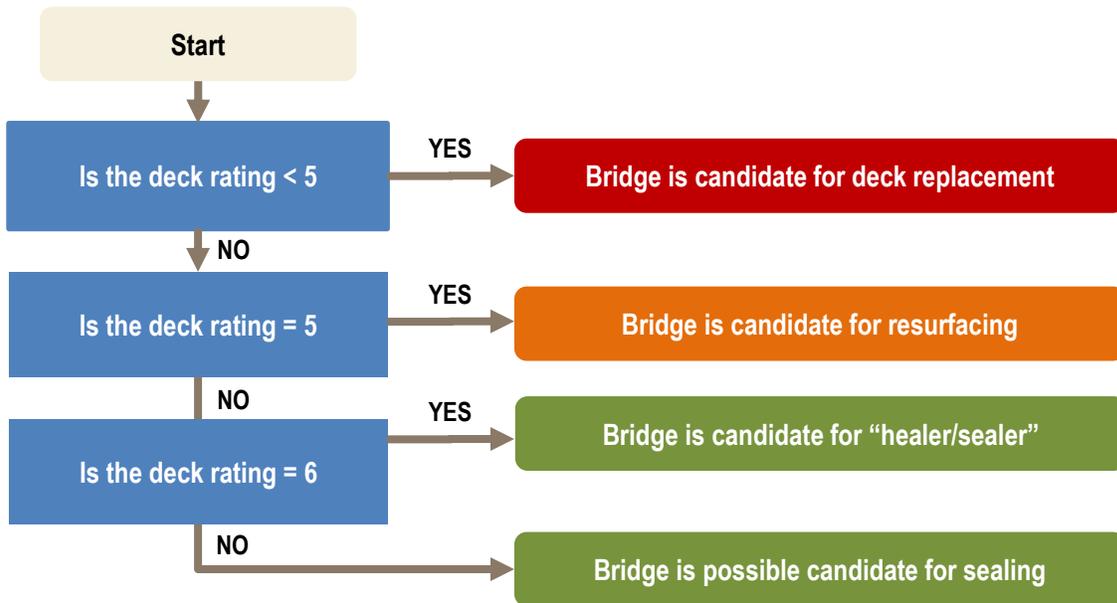
Figure 5-9 Bridge Improvement Type Decision Tree



MDT considers preservation activities for bridges in Good or Fair condition based on the potential for these activities to reduce life cycle costs and delay the need for more substantial and expensive bridge improvements.

Bridge decks generally deteriorate at a faster rate than other key bridge elements. Thus, MDT uses a bridge deck preservation decision process illustrated in Figure 5-10 to select appropriate deck work. Once MDT selects a bridge for deck work, the condition of other bridge elements is reviewed, and other structural work may be included if appropriate.

Figure 5-10 Bridge Deck Preservation Decision Tree



Life cycle cost implications of specific preservation treatments are also evaluated to assess their cost effectiveness relative to more substantial treatments. For example, the service life of a bridge deck is significantly less than other major bridge components. Consequently, assessing deck condition separately from overall bridge condition may enable MDT to defer the need for more costly bridge treatments such as rehabilitation or replacement when a bridge is otherwise in good condition.



6 GAP ANALYSIS

FHWA requires states to establish a process for conducting a performance gap analysis that identifies two things. The first is to identify alternative strategies to close the gaps between the current asset condition and targets for asset condition for the NHS. The second is to identify non-condition related gaps in the performance of the NHS that affect NHS pavements and bridges.

6.1 Gap Analysis Process

The MDT gap analysis process begins with establishing a vision for the SOGR for NHS pavements and bridges. MDT looks to several sources for guidance in establishing this vision, including the principles in MDT's mission, TranPlanMT, and the Montana Freight Plan. These were developed with public and stakeholder involvement and provide policy direction for the management of the Montana surface transportation program. Some guiding principles include:

- ★ **MDT mission** — To serve the public by providing a transportation system and services that emphasize quality, safety, cost effectiveness, economic vitality, and sensitivity to the environment.
- ★ **TranPlanMT policy goals**
 - **Safety** - Improve safety for all transportation users to achieve Vision Zero: zero fatalities and zero serious injuries on Montana roadways.
 - **System Preservation and Maintenance** — Preserve and maintain existing transportation infrastructure.
 - **Mobility and Economic Vitality** — Improve the safety, security, efficiency, and resiliency of freight transportation.
- ★ **Montana Freight Plan goal** — Alleviate freight mobility issues on state owned infrastructure.

MDT's 2- and 4-year pavement and bridge performance targets were also developed to align with these strategic planning goals and considered the same constraints and conditions. Therefore, efforts to achieve the SOGR will naturally result in MDT making progress toward and meeting the performance targets. Though this section is focused on SOGR, the gaps and strategies directly relate to performance targets.

6.2 NHS Pavements and Bridges State of Good Repair Levels

Based on these principles, MDT established the SOGR levels for NHS pavement and bridge condition demonstrated in Table 6-1.

Table 6-1 SOGR Levels for NHS Pavements and Bridge Condition

Pavement		
Interstate Pavement	80+	Ride Index
Non-Interstate NHS Pavement	76	Ride Index
Bridge		
NHS Bridge Deck Area	25%	Good
NHS Bridge Deck Area	3%	Poor

The TAMP considers performance gaps in terms of current condition and 10-year projected conditions based on the planned investment scenarios. Current condition gap is a comparison of the SOGR versus the most recent data collected. For the future gap, MDT begins by considering current condition, resources available for future investment, projected system condition based on deterioration and planned investment by treatment type, competing needs, and potential risks. This results in likely future condition. The difference between the condition and the SOGR level results in a system performance gap that can be related in terms of condition deficiency.

The result of MDT's condition gap analysis for NHS pavements and bridges is shown in Table 6-2. The analysis shows projected level of performance based on investment scenario between 2017 and 2027 and the SOGR threshold.

Table 6-2 NHS Pavement and Bridge SOGR Gaps 2017 and 2027

NHS Pavement Ride Index					
	SOGR Ride Index	Current Condition	Current Gap	Projected Condition (10-year)	Projected Gap
Interstate Pavement	80+	82	0.0	80+	0.0
Non-Interstate NHS Pavement	76	72.6	3.4	76	0.0
NHS Bridge Deck Area					
	SOGR % Square Feet	Current Condition	Current Gap	Projected Condition (10-year)	Projected Gap
Poor Condition	3%	7.3%	4.3%	3%	0.0
Good Condition	25%	17.4%	-7.6%	23%	2%

TranPlanMT provides strong direction for decision making to prioritize the use of available resources specific to system preservation and maintenance including:

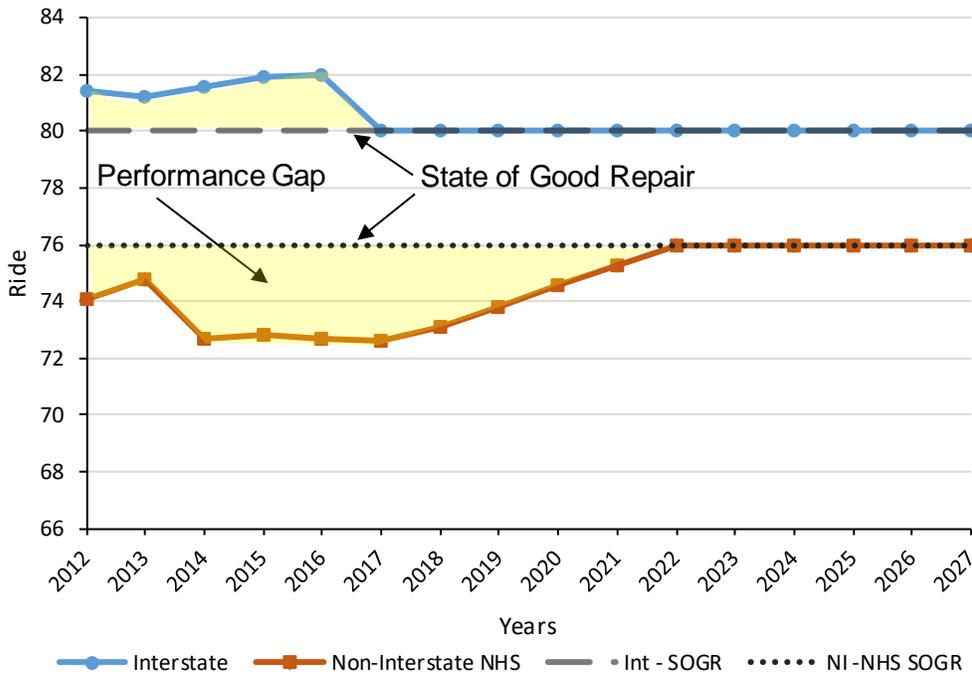
- ★ Employ an asset management approach to monitor system performance and develop an optimal investment plan ensuring like conditions throughout the state.
- ★ Provide the right improvements at the right time to manage infrastructure assets using cost-effective strategies.

MDT will continue to follow existing policy guidance to prioritize investments for NHS pavements and bridges. The Department anticipates achieving a desired SOGR on the NHS assuming there are no broad changes in available resources.

6.3 Predicting Future Pavement Conditions and Performance Gaps

Considering the current condition, expected deterioration, and planned level of investment, MDT plans to achieve the SOGR for Interstate and Non-Interstate NHS pavement condition within the 10-year plan horizon. Figure 6-1 shows this gap for pavement.

Figure 6-1 Future NHS Pavement Performance Gaps



Achieving SOGR is based on a continuation of investment practice adopted with the implementation of P3 in 1999, which prioritized pavement preservation activities. The objective of the program is to slow the rate of pavement deterioration, while providing a smooth, safe, and durable roadway at the lowest life cycle cost. This strategy includes establishing funding program set-aside allocations for preservation treatments. Pavement deterioration results from environmental factors and traffic volumes. As pavements deteriorate, structural and/or functional capacity is lost. Pavement preservation and rehabilitation improves pavement condition, extends pavement service life, postpones major reconstruction needs, and provides a safe driving surface.

MDT will continue to manage Interstate and Non-Interstate NHS pavement assets consistent with MDT policy direction and associated processes through:

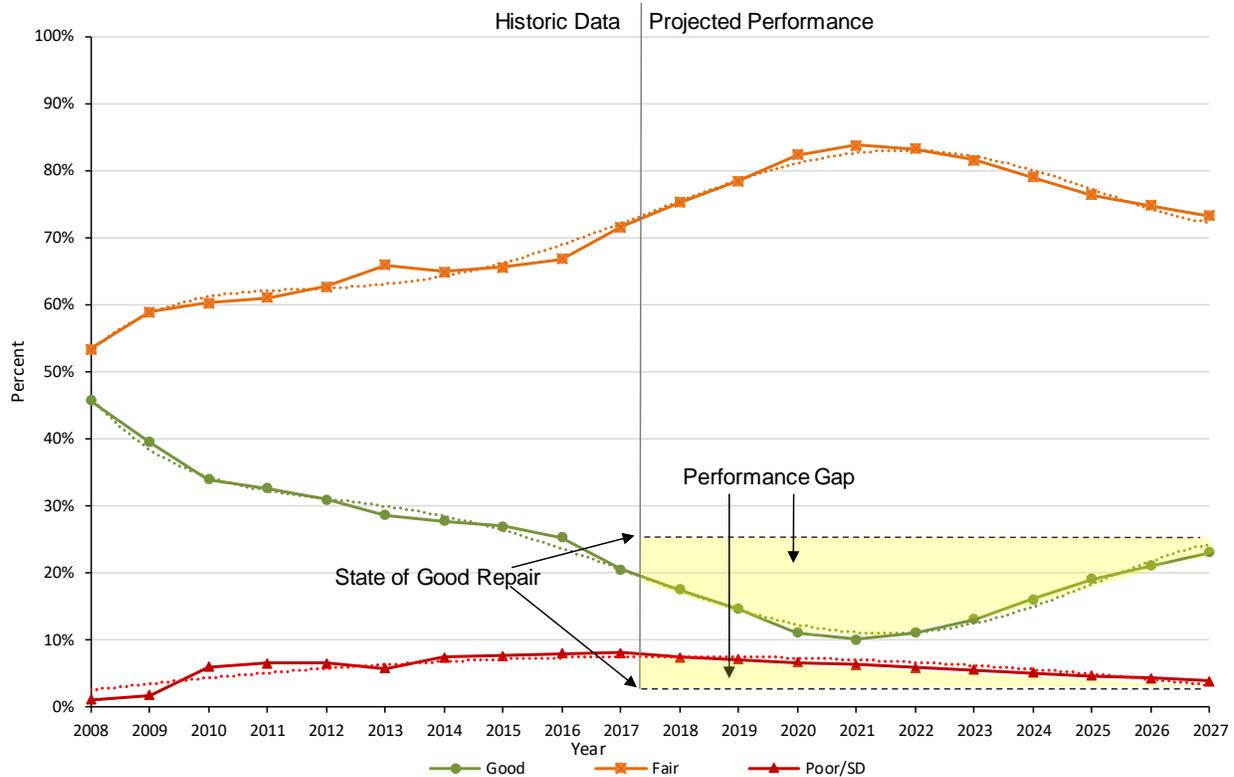
- ★ Aggressively applying preventive preservation solutions such as chip seals with each new surfacing project;
- ★ Deploying trained maintenance personnel and advanced technology to apply needed maintenance actions at the right time; and
- ★ Designing new facilities for durability and longer life using state-of-the-art materials and methods.

6.4 Projecting Future Bridge Conditions and Performance Gaps

MDT identifies potential bridge projects that balance competing needs and minimize life cycle costs. There is a direct relationship between funding levels, bridge conditions, and overall performance levels for NHS bridges. The impact of these potential projects on the condition of Montana bridges depends on the resources available to deliver these projects.

Presently, on the NHS there are significant gaps between current bridge conditions and MDT's desired SOGR as shown in Figure 6-2.

Figure 6-2 NHS Bridge Performance Gaps



To address these performance gaps, MDT increased allocations for NHS bridges by approximately \$15 million per year for a total \$40 million annual investment. This is a significant increase to the previous allocation of about \$25 million annually.

Prior to this increased funding, MDT performance models predicted that the percentage of Poor bridges by deck area on the NHS would rise above the 10 percent Federal threshold. The percentage of NHS Good bridges by deck area would continue to decline with little opportunity to reverse the trend.

The additional funding has improved this outlook. Most SD bridges on the NHS are included in construction projects that will be delivered in the next five years. Additionally, a series of bridge preservation and rehabilitation projects have been initiated to begin to address the downward trend in Good bridges. As MDT begins to make progress in addressing SD bridges, a shift of resources is anticipated from deck rehabilitation and replacement projects to more cost-effective preservation strategies.

MDT anticipates that NHS bridge performance will improve over time. However, there are additional factors that may impact future bridge performance on the NHS:

- ★ **Project delivery** — While MDT has identified and funded numerous NHS bridge projects, these projects take time to deliver. MDT is evaluating options such as innovative contracting to advance these projects as efficiently as possible.
- ★ **Bridge deck construction** — At times, MDT has experienced rapid deterioration in newly constructed bridge decks, which significantly impacts NHS bridge deck performance. As a result, the Department is implementing new material and construction specifications to address the issue.
- ★ **Timber bridges** — These bridges rapidly deteriorate from Fair to Poor condition. MDT has initiated a process to address many of these bridges and continues to closely monitor all timber bridges on the NHS.
- ★ **Overheight vehicles** — At times, NHS bridges have been struck by overheight vehicles resulting in structure damage and roadway closures. MDT is currently evaluating strategies to prevent these types of impacts and minimize the damage to bridges when they do occur.
- ★ **Seismic issues** — MDT proactively initiated seismic retrofits for many critical structures on the NHS to reduce vulnerability to bridges.
- ★ **Extreme weather events** — There have not been repeated failures on NHS routes caused by extreme weather or natural disasters. Isolated slides and flooding have occurred, but not as recurring or cyclical events.
- ★ **Reliability** — Overall, reliability is not an issue in Montana. Passenger vehicles and freight typically move freely and consistently on the NHS, though winter conditions occasionally interrupt travel on some NHS routes.

6.5 NHS Effectiveness Gap

System mobility can be associated with both reoccurring and non-reoccurring congestion. The state's relatively small population means reoccurring congestion is not a serious issue. Congestion that does occur is generally at peak hours for brief amounts of time.

Non-reoccurring events have a greater impact on mobility in Montana. Inclement weather and wildfires can have a considerable impact on the safe and effective movement of people and goods in and through the state.

An effectiveness gap analysis considers these non-condition related performance aspects of the Interstate and Non-Interstate NHS. MDT's mission and planning processes consider and account for non-condition related performance goals and need specifically for supporting safety, the economy, and mobility. Specific goals include:

- ★ **TranPlanMT** — Mobility and Economic Vitality: Facilitate the movement of people and goods recognizing the importance of economic vitality.
- ★ **Montana Freight Plan**
 - Reduce congestion to improve performance of the transportation system.
 - Improve safety, security, and resiliency of the transportation system.

MDT has processes as described below to address non-condition congestion and will continue to employ system performance strategies to address non-condition related system performance gaps.

6.5.1 Winter Maintenance

MDT's winter maintenance guidelines establish priorities, provide uniform service between maintenance areas and optimize resource allocation. Four levels of service guide route priority and consider the following factors:

- ★ **Safety**
- ★ **Annual Average Daily Traffic**
- ★ **School bus routes**
- ★ **Availability of alternate routes**
- ★ **Public interest and concern**
- ★ **Potential economic impact**
- ★ **Consequence of not providing higher level of service**
- ★ **Available resources**

MDT has approximately 900 maintenance personnel available to clear 25,000 lane miles of ice, slush, and snow during winter. Maintenance personnel prepare for winter by stockpiling necessary supplies prior to the season. In the fall, the same trucks that are used during the summer for stockpiling, patching, and other maintenance operations are equipped with snowplows.

MDT monitors road conditions using infrared sensors, thermal mapping, and Road Weather Information Systems (RWIS). Snowplow operators follow “just-in-time anti-icing” guidelines. Once the anti-icing work is completed, MDT responds to winter storms as they occur and attempts to clear all roads as snow continues to fall. In situations where a storm covers a large area, a system of priorities is followed to provide the most effective service.

Operational treatments are continuously evaluated by MDT before, during, and after winter storms. Road treatments and applications are modified through all phases of a storm based on analysis of intensity, duration, and type of precipitation.

6.5.2 Intersection and Signal Improvements

MDT has several on-going and completed initiatives to improve performance. These include signalized intersections, signal timing, and synchronization projects, advanced signal control, and data collection.

Proper traffic signal timing promotes safe and efficient traffic flow. A well-timed traffic signal system can reduce fuel consumption and emissions, eliminate unnecessary stops and delays, and increase safety. MDT Congestion Mitigation and Air Quality (CMAQ) Improvement Program funds are used for projects that improve corridor operations through upgrading traffic signal hardware and reviewing traffic signal timing.

MDT completed an Accelerated Innovation Deployment (AID) project in 2017 that includes a concept of operations for traffic signals across the state, guidelines for adaptive signal control, and evaluation of 14 corridors in seven urban areas. Through this process, MDT is exploring long-term options that have the potential to improve traffic flow through signalized corridors. Options currently being considered include improved monitoring of traffic signal performance, additional detection at signals, freight priority at traffic signals, and adaptive traffic signal control.

MDT tracks travel times on corridors for signal retiming using Bluetooth or Wi-Fi to capture data from vehicles. Using multiple sensors along a corridor allows for the anonymous tracking of a vehicle from point-to-point to establish travel times. Data is available in real time provided the portable sensors are placed on the corridor. MDT is currently looking to expand the use of Bluetooth monitoring.

6.5.3 Construction and Work Zone Planning

MDT Work Zone Safety and Mobility Policy uses the best management practice of minimizing or reducing impacts before they occur. During the project pre-construction phase, a project-specific Transportation Management Plan (TMP) is developed to address demand management, corridor/network management, construction zone safety management, and traffic/incident management.

6.5.4 Traveler Services Information

MDT's Traveler Information System provides travelers with timely, accurate roadway information. The traveler information program is continually evolving, but currently includes the following:

- ★ 511 toll-free phone system
- ★ Traveler information website
- ★ Mobile application
- ★ 73+ RWIS/cameras
- ★ Highway Advisory Radios (HAR)
- ★ Permanent and portable variable message signs
- ★ Snowplow cameras

The MDT website, www.mdt511.com, and the MDT travel information mobile application are widely used as sources for weather, construction and maintenance project information, reported incidents, road conditions, load and speed limit restrictions, and rest area locations and amenities. The 511 phone service provides route specific forecasting, regional reports, facility information, and access to surrounding states' road information.

The most recently deployed technology is snowplow cameras. While the plow is operating, dash-mounted cameras capture images about every half mile that are made available to the public via the MDT website and mobile app. This technology helps travelers determine conditions based on firsthand observations.

6.5.5 Corridor Planning

MDT conducts corridor planning studies to determine cost-effective solutions addressing transportation needs along a corridor. MDT invites local government and stakeholder representatives to assist in identifying corridor issues and concerns, potentially affected resources, and a range of options to improve transportation safety and operations. MDT uses the *Montana Business Process to link Planning Studies*, National Environmental Policy Act (NEPA), and Montana Environmental Policy Act (MEPA) to guide the process.

6.5.6 Highway Rail Crossings

MDT inventories all public at-grade crossings on a three-year cycle. The information collected is added to the MDT Highway-Rail Crossing Database and is reported to the Federal Railroad Administration (FRA) National Highway-Rail Crossing Database. This data is used to assess the safety of crossings and identify potential locations for safety improvements.

MDT monitors safety at highway-rail crossings and invests in safety improvements within available funding where improvements are feasible and cost effective. These efforts have continued to reduce the total number of highway-rail incidents in Montana.

Railroad companies continue to invest in capacity expansion as rail traffic increases. Train lengths are increasing, which affect vehicular delays at crossings. Longer trains may also impact crossings that are on sidings that weren't affected previously by shorter train lengths.

6.5.7 Natural Events

Various events, such as rock slides and flooding, may cause infrastructure failures or negatively impact system performance. When bottlenecks and delays result, MDT promptly initiates an incident management team to establish an appropriate detour. A second project team initiates the process to quickly implement repairs.

MDT strives to prevent failures before they occur. To prevent rockfalls, MDT utilizes a rockfall hazard rating process and system. The process and system screen for potential rockfall sites and rate sites according to estimated potential for rockfall on the roadway to prioritize areas of concern and respond effectively.

6.5.8 Wildfires

Wildland and rangeland fires are hazards that impact Montana every year. In mild fire seasons, there may be relatively small timber and crop resource losses. In extreme years, there can be resource devastation, habitat destruction, structure losses, and deaths. Transportation-related strategies for mitigating congestion and delay due to fires include removal of debris, such as burning trees near the roadway and provision for traffic control, if needed, to remove the debris. For evacuations, MDT personnel ensure that evacuation routes are safe and that information on safe, restricted, and closed routes is communicated to the proper authorities and the public.

6.5.9 Crash Delays

Depending on the severity, location, and alternate routes available, vehicle crashes can contribute to significant delay for highway users. If warranted and requested by the Montana Highway Patrol, MDT personnel will assist with traffic control until any investigation is complete and the roadway is cleared. Crashes are random in nature, but certain locations may exhibit a higher crash frequency than others. MDT has adopted an emergency operations and disaster plan that provides a basis for response to these types of events.

7 MANAGING RISK

The U.S. Department of Transportation defines risk as the positive or negative effects of uncertainty or variability upon agency objectives. Risk management is a process and framework for managing potential risks, including identifying, analyzing, evaluating, and addressing the risks to assets and system performance.

Major risk management elements within the context of the MDT asset management program and consistent with Federal rules include:

- ★ **Risk identification** — identify events that could impact MDT's ability to effectively manage pavements and bridges;
- ★ **Risk assessment** — assess the likelihood of an event happening and the consequences if that event does occur;
- ★ **Risk prioritization** — determine where to focus resources based on risk assessment;
- ★ **Risk treatment** — identify and implement a treatment or mitigation activity for each priority risk;
- ★ **Risk monitoring** — monitor and respond to possible events, evaluate the effectiveness of treatments, and periodically update risk priorities; and
- ★ **Emergency event evaluation** — summary evaluation of NHS pavements and bridges repeatedly damaged by emergency events.

7.1 Identifying, Assessing, and Prioritizing Risks

During the TAMP development and update process, MDT Executive, Engineering, Information Services (ISD), Planning, District, and Administration staff members assessed the likelihood and impacts of risks related to asset management. An online survey was distributed to agency staff across these functional areas to help identify, assess, and prioritize potential risks and provide insights in the following areas:

- ★ Identifying top three asset management risks;
- ★ Describing potential consequences of risks with respect to safety, mobility, asset damage, financial impact, and agency reputation;
- ★ Specifying the assets impacted by these risks;
- ★ Assessing the likelihoods of these risks occurring; and
- ★ Evaluating the consequences of these risks should they occur.

The survey resulted in a set of risks evaluated by the TAMP Steering Committee. Using the risks identified in the survey as a starting point, the Steering Committee finalized a list of 12 risks to include in the 2018 TAMP and assessed each through a formal evaluation process. As part of this process, the participants evaluated and scored each risk in the following categories:

- ★ **Risk likelihood** — risks are assigned a likelihood level based on probability of occurrence. Steering Committee members assessed risk likelihood on a 1 (low) to 5 (high) scale and responses were averaged to determine the overall score.
- ★ **Risk consequence** — risks are assigned a consequence level based on assumed impacts should they occur. Steering Committee members assessed these consequences related to the following factors:
 - **Safety** — the impact of the risk on fatal or serious injury crashes
 - **Mobility** — the impact of the risk on people and freight movement between locations
 - **Asset damage** — the impact of the risk on the physical and/or functional condition of an asset
 - **Financial** — the impact of the risk on agency or other costs pertaining to asset management

Values assigned by the Steering Committee were averaged for each category of impacts to determine overall safety, mobility, asset damage, and financial scores. The overall consequence level for each risk was then calculated as the weighted average of these scores. MDT considered all impact areas to be of equal importance and assigned each a weight of 25 percent.

- ★ **Risk level** —The Steering Committee calculated an overall risk level for each identified risk as the product of the risk likelihood score and risk consequence score. MDT used these scores to assign a priority level to each risk that is included in an overall risk register as shown in Table 7-1.

Table 7-1 Evaluating Risk Likelihood and Consequence

<i>Consequence Level</i>	1 <i>Negligible</i>	2 <i>Minor</i>	3 <i>Major</i>	4 <i>Critical</i>	5 <i>Catastrophic</i>
Likelihood Level					
1 Low	1	2	3	4	5
2 Medium Low	2	4	6	8	10
3 Medium	3	6	9	12	15
4 Medium High	4	8	12	16	20
5 High	5	10	15	20	25

7.2 Risk Management

The MDT risk management register in Table 7-2 identifies a prioritized set of risks and defines mitigation strategies for each. MDT will continue to monitor the risk landscape, the effectiveness of mitigation strategies, and will periodically update this risk register. MDT is currently conducting several of these mitigation strategies.

Table 7-2 Risk Management Register

Priority	Risk	Mitigation Strategy	Responsible
1	A. Change in political climate	<ul style="list-style-type: none"> Educate lawmakers on importance of asset management Formalize and document asset management processes so they are not easily disrupted Improve IT resources to enable scenario analysis and response to legislative inquiries 	<ul style="list-style-type: none"> Director's Office Planning Division Engineering Division
	B. Transportation funding is reduced by 20% in real dollars	<ul style="list-style-type: none"> Revert to TranPlanMT policy of preservation first and reassess funding levels 	<ul style="list-style-type: none"> Administrative Staff
	C. A freight-intensive market sector or unexpected development changes traffic volumes/patterns or negatively impacts infrastructure	<ul style="list-style-type: none"> Conduct impact reviews as part of permitting process Track changing traffic patterns so that management systems reflect impacts and ensure project development processes remain adaptable for addressing emerging conditions 	<ul style="list-style-type: none"> Planning Division Engineering Division, Motor Carrier Services & District Offices
2	D. Bubble in asset replacement needs due to uneven asset age distribution	<ul style="list-style-type: none"> Quantify and communicate the problem Implement use of NBIAS to assess opportunities to delay replacement by investing in bridge preservation, repair, and rehabilitation Finalize and implement asset management plan Rely on asset management to monitor and address long-term needs 	<ul style="list-style-type: none"> Engineering Division Engineering Division Planning Division Engineering & Planning Divisions
	E. Extreme weather event	<ul style="list-style-type: none"> Document emergency response protocol Set aside funds for routine emergency response Work with Federal partners to streamline emergency response process in terms of public involvement, environmental review, and right-of-way acquisition 	<ul style="list-style-type: none"> Planning Division Administrative Staff Planning Division
	F. Purchasing power decreases by more than 3% due to inflation, price volatility, mandates, etc.	<ul style="list-style-type: none"> Educate lawmakers on importance of asset management Coordinate with FHWA and AASHTO to address funding uncertainty at the national level Revert to TranPlanMT policy of preservation first and reassess programmatic funding levels 	<ul style="list-style-type: none"> Director's Office Director's Office Administrative Staff
	G. Emerging transportation technology (driverless vehicles, etc.)	<ul style="list-style-type: none"> Keep abreast of emerging technology and associated issues and opportunity, implement when beneficial (consider internal processes and external needs) Participate in national committees/discussions related to these technologies 	<ul style="list-style-type: none"> Engineering, Planning, Motor Carrier Services & Maintenance Divisions Engineering, Planning, Motor Carrier Services & Maintenance Divisions
3	H. Catastrophic infrastructure failure for reasons other than deterioration or scour (vehicle impact, natural disaster, etc.)	<ul style="list-style-type: none"> Implement seismic retrofit program Implement, update as needed, and ensure compliance with the Business Continuity Plan and Emergency Response Plan 	<ul style="list-style-type: none"> Engineering Division Maintenance Division
	I. Lack of internal or external staffing resources	<ul style="list-style-type: none"> Conduct succession planning throughout agency Update recruitment strategy to reflect changing workforce needs Implementing additional tools that allow use of additional resources (consultant services for contract administration) 	<ul style="list-style-type: none"> Human Resources Human Resources Administrative Staff
	J. Reduced flexibility with Federal funding	<ul style="list-style-type: none"> Revert to TranPlanMT policy of preservation first and reassess programmatic funding levels 	<ul style="list-style-type: none"> Administrative Staff
	K. Increased ongoing, seasonal weather events	<ul style="list-style-type: none"> Update hydraulic standards Continue practice of cleaning major culverts to ensure uninhibited flow 	<ul style="list-style-type: none"> Engineering Division Maintenance Division
4	L. Data, management systems, and other IT infrastructure are unable to support decision, analysis or business needs	<ul style="list-style-type: none"> Implement use of NBIAS and enhance Pavement Management System Enhance Financial Management Suite and Program & Project Management System Develop and implement a data governance plan 	<ul style="list-style-type: none"> Engineering Division Administration, Planning & Engineering Divisions Director's Office

Blue text indicates strategies MDT is currently conducting.

7.2.1 Reoccurring Repairs Caused by Emergency Events

Per 23 CFR 667, each state is required to conduct a statewide evaluation to determine if there are reasonable alternatives to roads, highways, and bridges that have required repair and reconstruction on two or more occasions due to emergency events. An emergency event is a natural disaster or catastrophic failure resulting in an emergency or disaster declaration by the Governor or the President of the United States.

This evaluation includes:

- ★ Identification and consideration of alternatives that will mitigate or resolve the root cause of the recurring damage;
- ★ Evaluation of risk of recurring damage and the cost of future repair under current and future environmental conditions; and
- ★ Analysis to achieve a solution, if possible, and document the costs and likely duration of the solution.

The evaluation period begins January 1, 1997, or earlier if useful data is reasonably available. MDT will update the evaluation documentation every four years, or when an emergency event occurs that requires the addition of a highway segment to the evaluation document.

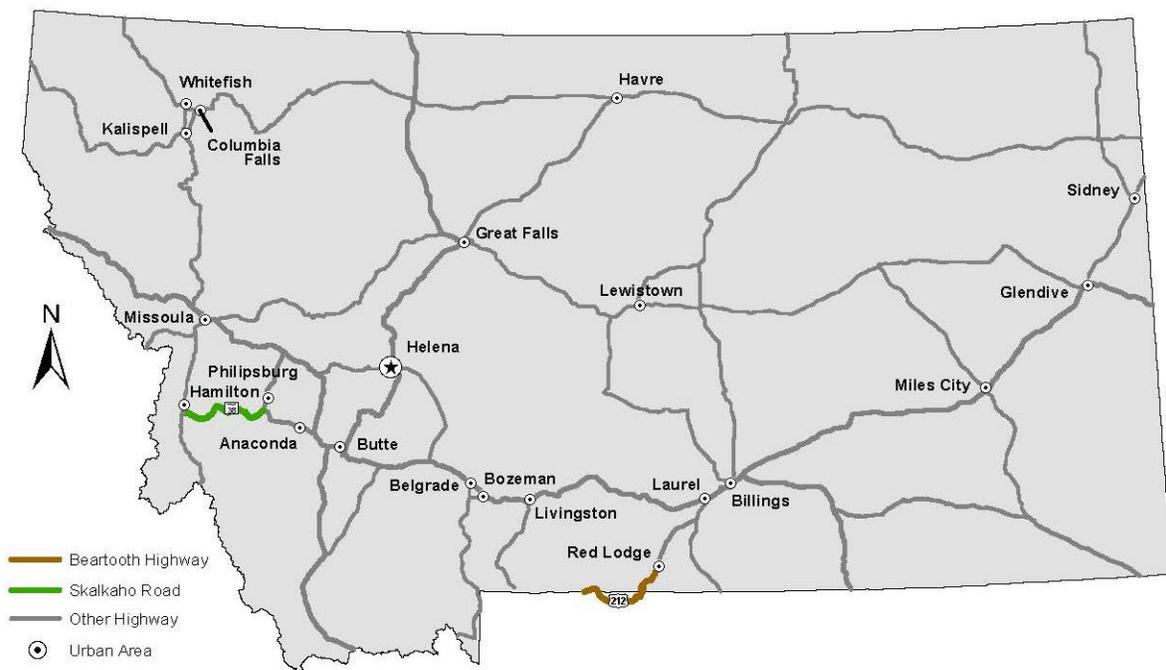
7.2.1.1 Evaluation Methodology

An initial review was conducted utilizing the MDT Program & Project Management System (PPMS) to identify emergency project locations on Federal-aid routes. This information was cross-referenced with the FHWA Financial Management Information System (FMIS) to confirm project locations. Lastly, MDT reviewed Emergency Relief (ER) Program documentation and State of Montana records to assess whether emergency projects were associated with disaster declarations.

7.2.1.2 Evaluation Results

MDT has identified two route segments that meet the criteria for having recurring emergency events as shown in Figure 7-1.

Figure 7-1 Non-NHS Recurring Emergency Event Locations



- ★ **Beartooth Highway** (US-212) is a seasonal route from Red Lodge to Yellowstone National Park via Cooke City. The highway experienced slope failures in 2005 and 2011 after excessive runoff/heavy rain that contributed to slope failures and debris flows. In 2005, approximately 10 miles was reconstructed at a cost exceeding \$20 million. In 2011, a minor repair project of less than \$100,000 was needed to clear debris and restore drainage to a culvert after a significant rain event. The Beartooth Highway is considered a National Scenic Byways All-American Road and is the Northeast Entrance to Yellowstone National Park. Consequently, no reasonable alternatives appear to exist for this roadway.
- ★ **Skalkaho Road** (MT-38) is a state highway that connects US-93 near Hamilton to MT-1 near Philipsburg. Portions of this roadway experienced minor damage from excessive runoff due to heavy rain. In 1997, the total cost for roadway repair work was about \$150,000. In 2011, restoration costs totaled slightly over \$300,000. No reasonable alternatives appear to exist for this seasonal highway as the nearest similar corridors are more than 40 miles in either direction.

Although no reasonable alternatives exist for these roadways, MDT conducted an analysis to mitigate the root cause of the recurring damage.

No locations were identified on the Interstate. Emergency events that impact Interstate routes are rare in Montana with occasional minor flooding and some slide activity, but no significant patterns have emerged to date.

No locations were identified on Non-Interstate NHS routes. A section of roadway on US-191 northeast of Lewistown near the Missouri River is potentially problematic. This section is prone to erosion events and slides. MDT has initiated a geotechnical study to evaluate mitigation options at this location.

Aside from the Beartooth Highway, no other locations were identified on Primary System routes. However, there are two areas of concern that are being monitored. The first location is on MT-80 north of Stanford near Arrow Creek. This area has highly erodible soils and is prone to slides. MDT has initiated a geotechnical study in this area to evaluate mitigation options.

The second area of concern is US-12 along the Musselshell River. In recent years, numerous high-water events have accelerated erosion along embankment areas near the roadway. MDT has advanced a series of bank stabilization projects to help address the issue and prevent damage from future high-water events.

No locations were identified on the Secondary Highway System. However, MDT is monitoring one site on Secondary 228 near Highwood that has historically been prone to slides.

Aside from Skalkaho Road, no other locations were identified on state highways or other Federal-aid routes.

7.3 Risk Management/Monitoring

MDT will evaluate the status of the top priority risks during the development of the annual national performance report and consider if mitigation measures remain effective and/or if different mitigations need to be implemented on a 2- and 4-year cycle, consistent with the TAMP update and target setting evaluation.

The Project Analysis Section of the Rail, Transit and Planning Division will perform the monitoring, and lead the TAMP update, the performance reporting, and the target setting processes.

8 FINANCIAL PLAN

8.1 Valuing Montana Assets

Infrastructure is defined as long-lived assets that are stationary in nature and can be preserved for a significantly greater number of years than most capital assets. Examples of infrastructure assets include roads, bridges, tunnels, drainage systems, water and sewer systems, dams, and lighting systems.

FHWA requires state TAMPs to include an estimate of asset value for NHS pavements and bridges, including the investment needed on an annual basis to maintain the asset value.

8.2 NHS Pavement and Bridge Asset Value

MDT considered two methods of asset valuation, including replacement value based on unit costs and Government Accounting Standards Board Statement No. 34 (GASB-34) depreciation method.

Replacement cost is a simple calculation based on unit costs per lane mile of pavement and per square foot for bridges. Estimates are based on assumed pavement widths and typical sections. Using this method, the NHS pavements replacement value is approximately \$7.5 billion, and NHS bridges replacement value is \$2.7 billion.

As standard business process, MDT conducts an annual infrastructure valuation to ensure compliance with *Montana Operations Manual*, Chapter 335: Capital Asset Accounting. Under Section III.B.3 of this manual, infrastructure is required to be capitalized at its historical cost and depreciated over its useful life. Annually, MDT uses the GASB-34 depreciation approach to determine the value of state infrastructure assets.

The GASB-34 depreciation method considers NHS asset value depreciated for service life and annual investment in capital activities to offset the loss in value. Using this method, the 2017 depreciated book value of NHS pavements and bridges was \$2.1 billion. During 2017, NHS pavements and bridges depreciated an estimated \$74.5 million, while MDT invested \$213 million in capital improvements and maintenance activities.

Using the GASB-34 method comparing the planned level of investment versus the annual depreciation, MDT will effectively maintain the value of NHS pavements and bridges.

8.3 Funding Sources

MDT's budget is a combination of state and Federal funds. Federal funds are provided through the FAST Act and state matching funds are provided through the biennial state budgeting process.

Funding for NHS pavements and bridges generally comes from the following sources:

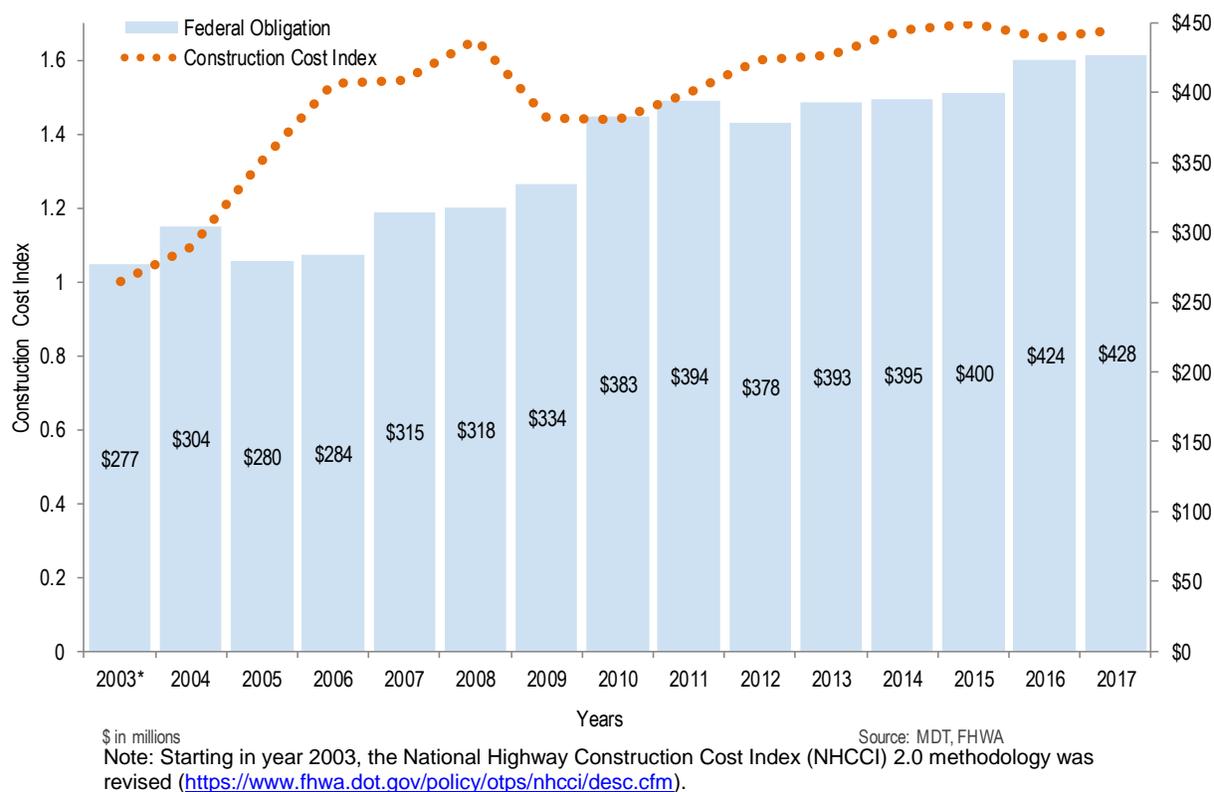
- ★ **NHPP** — provides funding to improve the condition and performance of pavements and bridges on the NHS. With the introduction of MAP-21 and the FAST Act, bridge funds now compete with other eligible activities within the NHPP funding pot.
- ★ **NHFP** — provides funding to improve efficient movement of freight on the National Highway Freight Network.
- ★ **SHSR** — matching funds are generated by state fuel taxes and vehicle weight permits and fees. The majority, 87 percent, of HSSR funds are constitutionally restricted for the construction, reconstruction, repair, operation, and maintenance of Montana Federal, state, and local highway roadway systems.

8.4 Balancing Needs and Funding

TranPlanMT sets MDT policy direction and vision and establishes strategies for how the statewide transportation system is managed and developed. To meet statewide priorities, MDT performs P3 tradeoff analyses and develops a performance-based Funding Distribution Plan. The aim of P3 is to balance available funding against needs and develop an optimal budget that delivers the best possible highway system performance outcomes. However, achieving targeted performance outcomes with increasingly limited funding is challenging.

National highway and street construction costs increased about 25 percent between 2006-2016 (*Global Insight 2016*). This reflects the increasing cost of key construction inputs, including labor, fuel, materials, and equipment. When construction costs and inflation increase at a faster pace than funding levels, the purchasing power of state and Federal funds decreases. As shown in Figure 8-1, Federal obligations to Montana continue to grow, but the value of those funds in real terms is not keeping pace with rising construction costs or overall statewide investment needs.

Figure 8-1 Federal Funding Flows and Inflation Indices



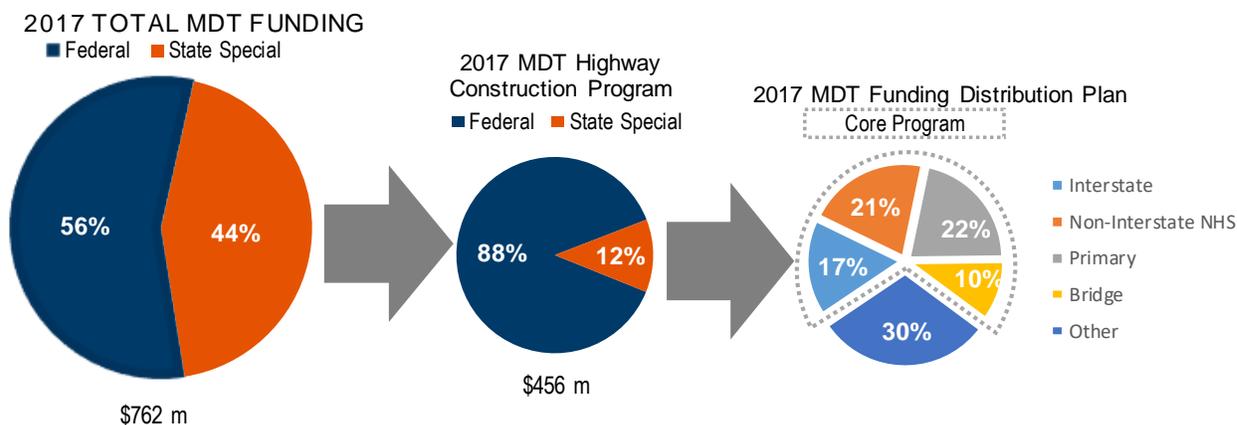
8.5 Allocating Funds for Asset Management

MDT managed approximately \$762 million in total funding in 2017 including Federal and SHSR. MDT allocates \$306 million, about 40 percent, of available state and Federal funds for general operations, planning, maintenance, multimodal activities, and for distribution to other state agencies and tribal and local governments.

The remaining \$456 million is directed to the Highway Construction Program. Typically, P3 uses approximately 70 percent of the Highway Construction Program for Core Program allocations. The P3-driven Core Program consists of Interstate, Non-Interstate NHS, Primary, and Bridge categories. The remaining distributions provided through state statute or Federal programs are included in the “Other” category for purposes of the TAMP.

Figure 8-2 illustrates how MDT funds are allocated from total funding allocations to the Core Program. This allocation by system is based on need as determined in P3.

Figure 8-2 MDT Funding Allocation



8.6 Anticipated Funding Levels

Annual allocation to the Core Program through P3 includes recommended funding for pavements and bridge by District, system (Interstate, Non-Interstate NHS, and Primary), and type of work (preservation, rehab, or reconstruction). MDT allocates funding to bridge and pavement programs to maintain target condition levels and are based on an analysis of the relationships between funding and performance. Table 8-1 displays anticipated Federal apportionment levels for the TAMP assets by MDT funding program to achieve the projected level of performance over the next 10 years.

Table 8-1 Total Apportioned Federal Funds* for TAMP Assets 2018-2027

	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Interstate Pavement										
Preservation	\$ 18.8	\$ 19.1	\$ 19.6	\$ 20.7	\$ 20.4	\$ 20.0	\$ 20.8	\$ 21.6	\$ 22.5	\$ 23.3
Rehabilitation	\$ 21.6	\$ 21.8	\$ 22.1	\$ 22.7	\$ 22.5	\$ 22.3	\$ 22.8	\$ 23.3	\$ 23.8	\$ 24.3
Reconstruction	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Other (non-pavement)	\$ 14.0	\$ 14.4	\$ 14.8	\$ 15.8	\$ 15.5	\$ 15.3	\$ 16.0	\$ 16.7	\$ 17.4	\$ 18.2
Total	\$ 54.4	\$ 55.3	\$ 56.5	\$ 59.2	\$ 58.4	\$ 57.6	\$ 59.6	\$ 61.6	\$ 63.7	\$ 65.8
NHS Pavement										
Preservation	\$ 18.0	\$ 20.2	\$ 22.5	\$ 24.7	\$ 28.2	\$ 29.5	\$ 31.9	\$ 34.4	\$ 37.2	\$ 40.1
Rehabilitation	\$ 19.0	\$ 20.4	\$ 21.5	\$ 22.9	\$ 24.6	\$ 25.3	\$ 26.6	\$ 27.9	\$ 29.4	\$ 31.0
Reconstruction	\$ 32.5	\$ 36.3	\$ 39.6	\$ 46.3	\$ 52.1	\$ 50.9	\$ 51.5	\$ 52.1	\$ 53.5	\$ 54.8
Other (non-pavement)	\$ 10.5	\$ 11.1	\$ 20.5	\$ 23.5	\$ 23.5	\$ 21.1	\$ 21.1	\$ 21.1	\$ 20.0	\$ 18.8
US-93 Bond Debt	\$ 15.1	\$ 15.1	\$ 3.8	\$ 3.8	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Total	\$ 95.1	\$ 103.1	\$ 107.9	\$ 121.2	\$ 128.4	\$ 126.8	\$ 131.1	\$ 135.5	\$ 140.1	\$ 144.7
NHS Bridges										
Preservation	\$ -	\$ 0.5	\$ 0.9	\$ 1.5	\$ 2.1	\$ 2.6	\$ 3.3	\$ 3.9	\$ 4.4	\$ 5.2
Rehabilitation	\$ 12.8	\$ 13.2	\$ 9.0	\$ 13.5	\$ 11.9	\$ 12.1	\$ 12.3	\$ 12.5	\$ 13.0	\$ 13.5
Reconstruction	\$ 19.1	\$ 19.5	\$ 5.9	\$ 17.0	\$ 19.0	\$ 19.4	\$ 19.7	\$ 20.0	\$ 21.0	\$ 22.0
Total	\$ 31.9	\$ 33.2	\$ 15.8	\$ 32.0	\$ 33.0	\$ 34.1	\$ 35.3	\$ 36.4	\$ 38.4	\$ 40.7

*\$ in millions of anticipated federal apportionment

For the purposes of this TAMP, MDT makes the following adjustments to estimated apportioned funds to reflect funds available for construction activities:

- ★ Reducing distribution values by 10 percent to account for Federal obligation limitation;
- ★ Further reducing distribution values by 18 percent to adjust for non-construction phases (design, right-of-way, etc.);
- ★ Removing non-pavement related investment needs, including but not limited to interchange/intersection work, guardrail, fencing, culverts, slide repair and bond debt service payments;
- ★ Increasing adjusted values to account for the state match of 8.76 percent for the Interstate program and 13.42 percent for all other programs.

This results in anticipated total funding for TAMP construction activities as shown in Table 8-2.

Table 8-2 Funds for TAMP Construction by MDT Funding Program/Work Type 2018-2027

	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Interstate Pavement										
Preservation	\$ 15.2	\$ 15.4	\$ 15.9	\$ 16.7	\$ 16.5	\$ 16.2	\$ 16.8	\$ 17.5	\$ 18.2	\$ 18.8
Rehabilitation	\$ 17.5	\$ 17.6	\$ 17.9	\$ 18.4	\$ 18.2	\$ 18.0	\$ 18.4	\$ 18.8	\$ 19.3	\$ 19.7
Reconstruction	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Other (non-pavement)	\$ 11.3	\$ 11.6	\$ 12.0	\$ 12.8	\$ 12.5	\$ 12.4	\$ 12.9	\$ 13.5	\$ 14.1	\$ 14.7
Pavement Total	\$ 32.7	\$ 33.0	\$ 33.8	\$ 35.1	\$ 34.7	\$ 34.2	\$ 35.2	\$ 36.3	\$ 37.5	\$ 38.5
NHS Pavement										
Preservation	\$ 15.3	\$ 17.2	\$ 19.2	\$ 21.1	\$ 24.0	\$ 25.1	\$ 27.2	\$ 29.3	\$ 31.7	\$ 34.2
Rehabilitation	\$ 16.2	\$ 17.4	\$ 18.3	\$ 19.5	\$ 21.0	\$ 21.6	\$ 22.7	\$ 23.8	\$ 25.1	\$ 26.4
Reconstruction	\$ 27.7	\$ 30.9	\$ 33.8	\$ 39.5	\$ 44.4	\$ 43.4	\$ 43.9	\$ 44.4	\$ 45.6	\$ 46.7
Other (non-pavement)	\$ 9.0	\$ 9.5	\$ 17.5	\$ 20.0	\$ 20.0	\$ 18.0	\$ 18.0	\$ 18.0	\$ 17.0	\$ 16.0
Pavement Total	\$ 59.2	\$ 65.5	\$ 71.3	\$ 80.1	\$ 89.4	\$ 90.1	\$ 93.8	\$ 97.5	\$ 102.4	\$ 107.3
NHS Bridges										
Preservation	\$ -	\$ 0.4	\$ 0.8	\$ 1.3	\$ 1.8	\$ 2.2	\$ 2.8	\$ 3.3	\$ 3.8	\$ 4.4
Rehabilitation	\$ 10.9	\$ 11.3	\$ 7.7	\$ 11.5	\$ 10.1	\$ 10.3	\$ 10.5	\$ 10.7	\$ 11.1	\$ 11.5
Reconstruction	\$ 16.3	\$ 16.6	\$ 5.0	\$ 14.5	\$ 16.2	\$ 16.5	\$ 16.8	\$ 17.0	\$ 17.9	\$ 18.8
Total	\$ 27.2	\$ 28.3	\$ 13.5	\$ 27.3	\$ 28.1	\$ 29.0	\$ 30.1	\$ 31.0	\$ 32.8	\$ 34.7

\$ in millions for CN/CE. Reduction includes obligation limitation, non-construction phases, non-pavement related investment, and addition of estimated state match.

MDT presents the P3 recommended funding levels to the Montana Transportation Commission for concurrence and uses P3 funding levels to develop a Funding Distribution Plan annually. Actual annual allocations for pavement and bridge projects are based on the best funding and condition data available when the Funding Distribution Plan is being developed. Not all allocations in the distribution plan are available to improve assets covered in this TAMP.

The P3 allocations for the TAMP assets are then aligned with MDT's policy-driven investment strategies, supported by the life cycle planning process, and with consideration of risks and non-condition performance needs. This results in a program of projects to ensure NHS pavement and bridge condition and progress toward achieving MDT performance targets, SOGR, and national performance goals.



9 INVESTMENT STRATEGIES

TranPlanMT provides the foundation for MDT's commitment to asset management and strong direction for investment strategies. The processes described in the TAMP, including P3, life cycle planning, risk management, and financial plan, follow the policy direction of TranPlanMT. These processes were developed to guide investment decisions and ensure that MDT optimizes available resources. Consistency among TranPlan MT, the TAMP, state and federal performance targets, and MDT's SOGR will lead to a program of projects in the STIP that will support state and national performance goals.

9.1 System Investment Related TranPlanMT Goals and Strategies

★ System Preservation and Maintenance

- GOAL: Preserve and maintain existing transportation infrastructure.
- STRATEGIES:
 - SPM1: Employ an asset management approach to monitor system performance and develop an optimal investment plan ensuring like conditions throughout the state.
 - SPM2: Provide the right improvements at the right time to manage infrastructure assets using cost-effective strategies.
 - SPM3: Design new facilities for durability and longer life cycles using state-of-the-art materials and methods.

★ Business Operations and Management

- GOAL: Provide efficient, cost-effective management and operation to accelerate transportation project delivery and ensure system reliability.
- STRATEGIES:
 - BOM1: Coordinate with state and Federal agencies to support transportation security and enable appropriate response and recovery from emergency and disaster situations.
 - BOM2: Develop and implement a long-range multimodal transportation improvement program that addresses Montana's statewide transportation needs, is consistent with the statewide long-range transportation plan and management system output and maximizes the use of Federal funds through P3 to ensure a cost-effective, efficient, and safe transportation system.

- BOM5: Invest at the appropriate level to achieve performance targets given available funding.
- BOM6: Employ proactive management strategies to ensure compliance with rules and regulations, identify risk to MDT and the transportation network, and facilitate equitable participation in MDT programs and services.

MDT's asset investment strategies were developed in consideration of various funding scenarios, short-term condition goals and targets, and long-range policy direction consistent with achieving or making progress toward the desired SOGR. The strategies and resulting funding allocation decisions are supported by processes and data analysis that consider existing conditions, rates of deterioration, risks, and projected revenues to achieve the optimal investment with the limited resources available.

9.2 Federal Requirements

FHWA requires states to include investment strategies as part of the asset management plan. Investment strategies are defined as:

“A set of strategies that result from evaluating various levels of funding to achieve State DOT targets for asset condition and system performance effectiveness at a minimum practicable cost while managing risk.”

The asset management plan describes how the investment strategies will collectively make or support progress toward achieving or sustaining an SOGR over the life cycle of the assets, improve or preserve the condition of the NHS assets, achieve the state's 2- and 4-year targets for the condition of the NHS assets, and the process for developing the investment strategies.

9.3 MDT Strategies

The following strategies provide high-level investment direction based on TranPlanMT policy guidance, supported by Department processes and procedures, and provide MDT's investment vision to preserve and protect the state and Federal investment in Montana's highway system.

When developing each of these investment strategies, MDT considered the life cycle planning analysis, financial planning, risk analysis, SOGR, and performance targets. Considerations:

- ★ **Life cycle planning and gap analysis** — The performance gap analysis, supported by life cycle planning, establishes the scope and scale of future investment needed to optimize asset conditions while minimizing costs.
- ★ **Future funding** — Identifies the resources available to address those investment needs identified in the gap analysis/life cycle plan and determines if condition optimization is possible. Generally, needs outpace resources available, so funding is a constraining factor in achieving the desired SOGR.
- ★ **Risk assessment** — Risk introduces an additional variable that may pull available funding away from identified needs, further reducing the ability to achieve performance targets and/or the desired SOGR. As described in the risk register, MDT has taken steps to mitigate the negative impact of risk to the program.
- ★ **State of good repair** — MDT's SOGR is based on the gap/life cycle planning recommendations to optimize performance at the least cost with consideration of public and stakeholder input through the policies established in TranPlanMT.
- ★ **Performance targets** — Targets are reasonable and achievable levels of performance considering the gap/life cycle planning recommendations, future funding available for asset investment, and an assessment of the risks that may negatively affect system condition and performance.

9.4 Investment Scenarios

- ★ **Right Treatment at the Right Time** — TranPlanMT goals related to investments emphasize making the right treatment at the right time focusing on preventative and rehabilitative efforts to cost effectively manage existing infrastructure and avoid expensive deferred maintenance. This approach enables prudent use of taxpayers' funding by slowing deterioration rates and extending the life of infrastructure.
- ★ **Preservation**
 - MDT has a long history of focusing on preserving and maintaining the existing infrastructure. To ensure that preservation activities do not compete with capital construction projects, MDT established funding program set asides to be used on pavement preservation projects. These set asides also benefit bridge condition. If there are bridges in the pavement preservation project limits, MDT will also perform bridge preservation activities.
 - MDT is taking advantage of more flexible bridge program eligibilities provided through MAP-21 with an increased focus on preservation activities.
- ★ **Targeted Assets** — Coupled with preservation activities, MDT will also target certain asset categories for increased investment to address current condition deficiencies and to mitigate risks. For example, MDT is directing NHFP funds to address bridge condition for freight reliability.

These investment practices allow MDT to protect the existing investment in pavement and bridge condition, provide an extended service life, which delays the need for expensive reconstruction projects, and make additional targeted investments to improve asset conditions and mitigate risk.

Through these strategies, continuing the focus on pavement preservation and increasing efforts on bridge preservation, MDT is projected to continue to make progress toward achieving and meeting the state's pavement and bridge condition performance targets and SOGR. This will collectively support MDT's continued progress toward, and achievement of, meeting the national performance goals established by MAP-21 for minimum pavement condition on the Interstate and structurally deficient deck area of NHS bridges.



10 FUTURE TAMP ENHANCEMENTS

MDT recognizes that condition, performance, and process gaps exist related to risk-based asset management. A comprehensive gap assessment was performed during TAMP development. Potential enhancements to strengthen MDT asset management practices were identified.

10.1 Data and Process Gaps

MDT continues to collect and analyze infrastructure condition data for making optimal investment and improvement decisions in terms that make good sense for Montana. While developing the TAMP and establishing national performance targets, MDT staff uncovered several gaps related to data and analysis capabilities.

The recent Federal rulemaking for asset management and performance management differ from those historically used by MDT. This presents a gap in using past practice to generate good trends in performance in terms of the required national metrics. This data shift extends from collection to changes in HPMS data submittal and reporting. The result of this precludes using HPMS reports based on past submittals to generate trends for future decision making.

In addition, MDT recently updated the bridge inventory system, but does not have a bridge analysis tool. MDT does have metrics for making data driven bridge investment decisions, but the process is generally manual and limits MDT's ability to perform system-wide investment optimization scenarios.

MDT is addressing the data/process gaps as follows:

- ★ **Enhancing the Pavement Management System** — PvMS recommends treatments based on an optimization approach using pavement ride quality. MDT is currently working to improve cracking analysis, modeling, and reporting capabilities. MDT is investigating how to combine the guidance reporting elements of pavement performance in PvMS and capture the combined measures in future condition scenarios.

- ★ **Implementing NBIAS for Bridge Management** — MDT Bridge Management staff has begun testing NBIAS to support bridge management investment decisions which includes the following:
 - Forecast bridge deterioration;
 - Evaluate life cycle costs;
 - Identify short and long-term budget needs; and
 - Recommend optimal work strategies and implementation schedules.

10.2 Process Gaps

MDT staff completed the self-assessment survey from Volume I of the *AASHTO Asset Management Guide* to help assess MDT in terms of state-of-the-art asset management practices. MDT managers participated in interviews regarding existing practices and potential opportunities for improvement. MDT staff also participated in a self-assessment workshop that provided insights and established consensus on priorities for improvement.

Based on this input, priorities for enhancing the asset management program include:

- ★ **Clarifying Alignment between P3 and the 5-year Tentative Construction Program (TCP)** — This initiative addresses the potential disconnect between the program-level funding decisions made during P3 and final allocation of funds in the TCP. MDT will address this issue by:
 - Further documenting the TCP development process;
 - Clarifying the impact of how transfers between programs and District-specific factors impede the agency's ability to meet the goals, objectives, and targets established through P3; and
 - Further documenting the process used to verify the TCP is consistent with P3 results.
- ★ **Improving Coordination Between Maintenance and Capital Activities** — This initiative is aimed at taking a comprehensive view of potential asset treatments and minimizing budget and organizational constraints for implementation. The initiative involves:
 - Identifying strategies for effectively managing pavements throughout the pavement life;
 - Determining the most efficient way to implement each strategy such as using Maintenance forces versus a capital project or internal staff versus contractor staff; and
 - Pursuing funding and ensuring the MDT Maintenance program has the training, equipment, and staffing capacity for implementing such strategies.
- ★ **Developing a Transportation Asset Management Information System (TAMIS)** — MDT is making advancements in data and information systems to support asset management decisions. A TAMIS is a set of software and business processes that help turn data from multiple systems into useable information. A TAMIS can help ensure that MDT implements future systems and system updates that maximize the ability to support asset management. Potential elements of a TAMIS include:
 - An enterprise data dictionary that defines core data items;
 - A data governance plan that identifies responsibility for collecting and managing core data items, defines a source of record for each item, and documents a data quality assurance/quality control process;
 - Linear Referencing System standards that enable data from multiple systems to be integrated efficiently via Geographic Information System;
 - Dashboards, mapping systems, and other applications that enable staff to quickly query and obtain data from multiple sources; and
 - A system architecture that illustrates how core systems currently interact and provides a vision for future interaction.

- ★ **Addressing Additional Assets in the Asset Management Program** — MDT's initial asset management focus is on bridges and pavements. Longer term, MDT will work to develop formal asset management programs for other assets. In determining priorities for additional assets, MDT will:
- Assess the relative risk for asset groups;
 - Assess the degree to proactively mitigate the risk of failure;
 - Estimate the costs of implementing and sustaining each asset management element; and
 - Compare implementation costs to asset failure costs and determine elements, if any, to implement.

11 ACRONYMS

AID	Accelerated Innovation Deployment
ACI	Alligator Crack Index
ADCV	Automated Data Collection Vehicles
BAT	Bridge Analysis Tool
BMS	Bridge Management Section
CMAQ	Congestion Mitigation and Air Quality
ER	Emergency Relief
FHWA	Federal Highway Administration
FRA	Federal Railroad Administration
FMIS	Financial Management Information System
FAST Act	Fixing America's Surface Transportation Act
GASB-34	Government Accounting Standards Board Statement No. 34
HAR	Highway Advisory Radio
HPMS	Highway Performance Monitoring System
HSIP	Highway Safety Improvement Program
ISD	Information Services
IRI	International Roughness Index
LCCA	Life Cycle Cost Analysis
LCP	Life Cycle Plan
MP	Metropolitan Planning Organizations
MCI	Miscellaneous Crack Index
CHSP	Montana Comprehensive Highway Safety Plan
MDT	Montana Department of Transportation
MEPA	Montana Environmental Policy Act
MAP-21	Moving Ahead for Progress in the 21st Century Act
NBE	National Bridge Element
NBI	National Bridge Inventory
NBIS	National Bridge Inspection Standards
NEPA	National Environmental Policy Act
NHFP	National Highway Freight Program
NHPP	National Highway Performance Program
NHS	National Highway System
PvMS	Pavement Management System
P3	Performance Programming Process
RI	Ride Index
RWIS	Road Weather Information Systems
SHSR	State Highway Special Revenue
SOG	State of Good Repair
STIP	Statewide Transportation Improvement Program
SD	Structurally Deficient
SMS	Structure Management System
TCP	Tentative Construction Program
TAMIS	Transportation Asset Management Information System
TAMP	Transportation Asset Management Plan
TMP	Transportation Management Plan

APPENDIX A — DATA QUALITY PLAN

Montana Department of Transportation

Network-Level Pavement Condition Data Collection Quality Management Plan

Version 1.0

Prepared By: M.G. Padmos – Pavement Management Engineer
4-12-2018

Introduction

The Montana Department of Transportation (MDT) began automated pavement condition surveys in 2011 using equipment purchased from Pathway Services. Prior to 2011, MDT collected cracking distress manually and used ICC profilers to collect ride, rut and faulting. The Pathway vehicles purchased in 2011 are fully automated for crack detection, profile, rut, faulting data analysis used for distress scoring. Along with the pavement distress collection, MDT equipped the vans with a gyro for geometric data collection and cameras for video-log.



Data Collection

MDT collects pavement condition data on approximately 22,000 lane miles annually. This encompasses all lanes in both directions on the following systems: Interstate, Non-Interstate National Highway, State Primary, State Secondary and requested Urban and Off- system routes to support Highway Performance Monitoring System (HPMS). Road profile data collected as part of the network-level pavement condition data is recorded for every 0.1 mile of the surveyed length.

Distress data continuously collected as part of the network-level pavement condition is recorded at every one-tenth mile of surveyed length. MDT manages by segment length for MDT's Pavement Management System (PvMS), whereas HPMS reports at the 0.1 mile. MDT collects data over 100 percent of the length of the network. The collected data is shown in the following table.

Network Level Condition Data Items Collected

General Data	Asphalt Pavements	Concrete Pavements
<ul style="list-style-type: none">• GPS coordinates (longitude, latitude and elevation)• Location (route, reference point, and direction)• Optional Geometric data (cross slope and curvature)• Perspective and ROW Images	<ul style="list-style-type: none">• Alligator cracking• Miscellaneous (transverse, and longitudinal) cracking• Rutting• IRI	<ul style="list-style-type: none">• Transverse cracking• Longitudinal cracking• Crack Spalling• Joint faulting• Rutting• IRI

Collection File

MDT Pavement Management unit develops a collection file identifying each segment (called nodes) to be collected along with a physical description and GPS coordinates of the node's beginning and ending point. In addition, the agency develops a shape file of the network using GIS software for the van operator to visualize the segments. The Pavement Management unit uses these files to route the collection efficiently and to compare against the collected segments to ensure complete collection coverage.

Document Change Control

The following is the document control for revisions to this document.

Version Number	Date of Issue	Author(s)	Brief Description of Change
1.0	April 2018	M.G. Padmos	Initial Publication

Definitions

The following are definitions of terms, abbreviations, and acronyms used in this document.

Term	Definition
AASHTO	American Association of State Highway and Transportation Officials
ASTM	American Society of Testing and Materials
DMI	Distance Measuring Instrument
GPS	Global Positioning Systems
HPMS	Highway Performance Monitoring System
IP	Inertial Profiler
IRI	International Roughness Index
LTPP	Long-Term Pavement Performance
PvMS	Pavement Management System
QC	Quality Control
QM	Quality Management

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1. Quality Management Approach.
2. Deliverables, Protocols, and Quality Standards.
3. Quality Control.
4. Acceptance.
5. Quality Team Roles and Responsibilities.
6. Quality Reporting Plan.
7. Acceptance of QM Plan.

1. QUALITY MANAGEMENT APPROACH

The purpose of managing quality is to validate the deliverables are completed with an acceptable level of quality. Quality management (QM) assures the quality of the data collection deliverables and describes the processes and procedures to be used for ensuring quality.

The QM plan identifies key activities, processes, and procedures for ensuring quality. Below is a brief explanation of each of the sections of the QM plan that follow.

Section 2. Deliverables, Protocols, and Quality Standards	The data collection deliverables subject to quality review, protocols used to collect, and quality standards that are the measures used to determine a successful outcome for a deliverable. The criteria to describe when each deliverable is considered complete and correct are defined by the pavement management engineer. Deliverables are evaluated against these criteria before they are formally approved.
Section 3. Quality Control (QC)	The QC activities that monitor, provide feedback, and verify that the data collection deliverables meet the defined quality standards.
Section 4. Acceptance	The acceptance testing that will be used to determine if quality criteria are met and corrective actions that will be taken for any deliverables not meeting criteria.
Section 5. Quality Team Roles and Responsibilities	The quality-related responsibilities of the data collection team.
Section 6. Quality Reporting Plan	The documentation of all QM activities—including quality standards, QC, acceptance, and corrective actions—and the format of the final QM report.
Section 7. Acceptance of QM Plan	Signature page for acceptance of the QM Plan.

2. DELIVERABLES, PROTOCOLS, AND QUALITY STANDARDS

The key deliverables, protocols used for collection, and associated quality standards are described below. Quality standards define, when applicable, the resolution, accuracy, and repeatability or other standards that will be used to determine the quality of each deliverable. See Section 4 for the Acceptance Testing Plan.

Deliverable	Protocols	Resolution	Accuracy (compared to reference value)	Repeatability (for three repeat runs)
Longitudinal Profile	AAAHTO: M 328-14 PP 70-14 R 56-14 R 57-14 ASTM E950	1 in/mi	± 5 percent	± 5 percent
IRI (left, right, and average)	AASHTO: M 328-14 R43-13 R 57-14 ASTM E1926	1 in/mi	± 5 percent	± 5 percent
Rut depth (average and maximum)	AASHTO: PP 69-14 PP 70-14 R 48-10	0.01 in	± 0.06 in	± 0.06 in
Faulting (average over 0.2 in)	AASHTO: R 36-17	0.01 in	± 0.06 in	± 0.06 in
Distress Identification and Ratings	AASHTO: PP 67-14 PP 68-14 R 55-10 ASTM E1656/E1656M-11, LTPP Distress Identification Manual MDT Distress Manual (2010)	Varies	± 20 percent	N/A
GPS (latitude and longitude)	N/A	0.00001 degree	± 0.00005 degree	± 0.00005 degree
Cross slope	N/A	0.1 percent	± 0.5 percent	± 0.5 percent

Deliverable	Protocols	Resolution	Accuracy (compared to reference value)	Repeatability (for three repeat runs)
Location of segment	N/A	N/A	All assigned segments surveyed & assigned correct location	N/A
Perspective and ROW images	N/A	N/A	Signs legible, proper exposure and color balance	N/A
Pavement images	N/A	N/A	1/8 in. wide cracking visible on asphalt and concrete pavements	N/A

3. QUALITY CONTROL (QC)

The focus of QC is on data collection deliverables and processes. QC monitors the deliverables to verify that they are of acceptable quality and are complete and correct. The following table identifies:

- The major deliverables that will be tested for satisfactory quality level.
- The quality expectations for the deliverables.
- The QC activities that will be executed to control and monitor the quality of the deliverables.
- How often or when the QC activities will be performed.

Deliverable	Quality Expectations	QC Activity	Frequency/Interval
IRI, rut depth, faulting, GPS coordinates, DMI, cross slope, and longitudinal grade	95 percent compliance with standards	Initial equipment configuration, calibration, verification	Pre-collection - annually
		Daily equipment checks and monitor real-time	Daily
		End of day collection review	Daily
		Control, blind, or verification testing	Weekly
		Inspect uploaded data samples	Weekly
		Inspect processed data	During QC
		Final data review	Prior to PvMS acceptance
Distress ratings	80 percent match: Manual checks vs Automated	Equipment configuration, control site rating calibration and verification	Pre-collection
		Blind verification checks	Weekly
		Intra-rater checks	During QC
		Final data review	Prior to PvMS import

Deliverable	Quality Expectations	QC Activity	Frequency/Interval
Location of segment and begin point	98 percent compliance with standards	Mileage review	Pre-collection and Daily
		Comparison with the master route file	Daily and Weekly
		GIS comparison	Prior to delivery
		Final data review	Prior to delivery
Perspective, ROW and pavement images	98 percent compliance with standards for main travel lane and not more than 5 consecutive images failing to meet criteria	Startup checks, real-time monitoring, and field review	Daily
		Uploaded collection review	Weekly
		Final review	Prior to delivery

Pavement Condition Data Collection Vehicle Calibration

With the assistance of a Pathway Services technician, MDT calibrates/tests the pavement condition data collection vehicles once a year for IRI, Rut, DMI and images. This is done in the spring before roadway collection begins.

Block Calibration

The block test is used to calibrate the right and left wheel path lasers.

- 10 measurements are taken on 4 different sized blocks of known thickness. The thickness of each block is as follows: 0.25'', 0.50'', 1.00'' and 2.00''.
- The 10 measurements for each block are then averaged to get 1 average measurement that will be compared to the actual thicknesses.
- The acceptable tolerances are as follows:
 - For the 0.25'', 0.50'' and 1.00'' blocks, the acceptable tolerance is $\pm 0.005''$
 - For the 2.00'' block, the acceptable tolerance is $\pm 0.01''$
- An official document summarizing the test results is produced and signed by a Pathway Services technician. Figure 1 below is an example of a passing block calibration for one of the wheel path lasers.
- If an average for any block does not fall within the acceptable range, the laser will be recalibrated, and the block test will be repeated for that block size.



Pathway Services Inc.

AUTOMATED ROAD AND PAVEMENT CONDITION SURVEYS
 P.O. BOX 472105 TULSA, OK 74147 | PH: 918.259.9883 | FAX: 918.259.9912

Van: H12 174 "NORTH"

Left Wheel Path

Date: 5/1/2017

Test Number	Block Height (Inches)				
	Base Plate	0.25"	0.50"	1.00"	2.00"
1	0.000	0.251	0.501	1.000	1.997
2	0.000	0.250	0.503	0.999	1.997
3	0.000	0.250	0.501	0.998	1.997
4	0.000	0.251	0.502	0.999	1.997
5	0.000	0.250	0.502	0.999	1.998
6	0.000	0.250	0.505	1.000	1.999
7	0.000	0.249	0.504	1.001	1.998
8	0.000	0.250	0.501	1.000	1.998
9	0.000	0.249	0.502	1.000	1.997
10	0.000	0.251	0.503	0.997	1.998
Actual Block	0	0.2500	0.5000	1.0000	2.0000
Average	0	0.2501	0.5024	0.9993	1.9976
Difference	0	1E-04	0.0024	0.0007	0.0024
Stand. Deviation	0	0.000738	0.00135	0.00116	0.000699
Max.	0	0.251	0.505	1.001	1.999
Min.	0	0.249	0.501	0.997	1.997

Pathway Services, Inc. certifies the above listed vehicle has been calibrated and tested per AASHTO standards as stated in AASHTO Designation: R56-10 (2010) and PP 49-03 (2005) for Static Tests.

Jeremy Rockefeller, Project Manager Date

Figure 1: Passing Block Calibration

Bounce Test

The bounce test verifies the proper function of the accelerometers with relation to the wheel path lasers.

- The bounce test is only performed once and produces two graphs for the left and right wheel path lasers/accelerometers. Figure 2 shown below is an example of a Bounce test result for one of the wheel path lasers/accelerometers.
- The graphs are visually inspected by the Pathway Services technician and MDT operators for the following criteria:
 - Blue line should be as close to flat as possible $\pm 0.003'$
 - Red and black waves should be identical in amplitude.
- If the vehicle system(s) are not within tolerances after MDT operator's multiple attempts, the manufacturer will be contacted for further instructions or recommendations to bring it within tolerance.

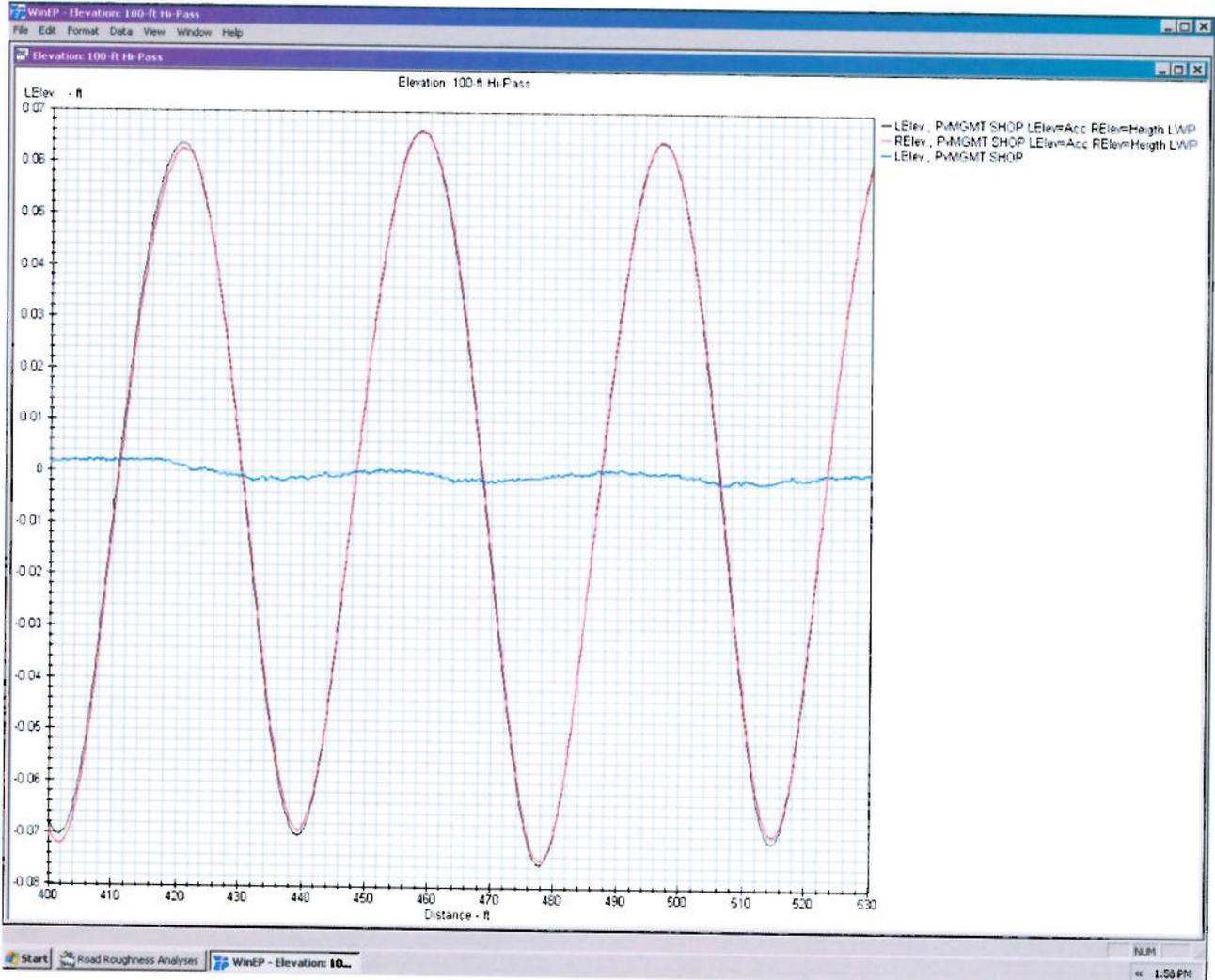


Figure 2: Bounce Graph

Distance Measuring Instrument (DMI)

The DMI calibration is done to ensure the vehicle is accurately measuring a specific distance between two points. Recalibration is done weekly to account for tire wear or new tires.

- The calibration site is 1-mile long, the distance between the two points is of survey precision.
- The start and end collection points are triggered using a photocell and reflective tape to eliminate any human error.
- The resulting Distance Correction Factor (DCF) from the DMI calibration is a calculation of how many pulses are recorded for a specific distance.

Images

Test data is collected to verify the perspective, ROW and 3D pavement images are calibrated correctly. The images are visual inspected by the Pathway Services technician and MDT operators for the following criteria:

- The perspective and ROW images are inspected for clarity, brightness and alignment. If it is found that the images need adjusting for any of the criteria, the cameras will be adjusted until they are of satisfactory quality. (Note: if the perspective camera needs an alignment adjustment, the camera will be recalibrated for lane width, location, height and distance measurements).
- The 3D pavement images (profile and intensity) are inspected for clarity and brightness. If the images are of unsatisfactory quality, the camera and line lasers that work in conjunction to create the images will be recalibrated.

5-Mile Baseline

After the block and bounce calibrations have been completed each van makes 10 runs on a verification site that is 5 miles in length. The site is an asphalt pavement not scheduled for construction or maintenance, so the condition stays constant during the collection cycle.

- The 10 runs are then processed and loaded into an Excel spreadsheet provided by Pathway Services and averaged to get a baseline which will be the basis for all subsequent weekly verifications.
- (Note: in the future the pavement management section may create ERD files for each run and compare them in ProVAL and set tolerances for repeatability and accuracy.)

Distress Detection Ground Truth

Before data collection begins, each van makes a single run on one or more calibration sections covering a range of distresses. Like the baseline section for IRI, and Rutting, the cracking section or sections should not be scheduled for construction or maintenance.

- After processing the crack analysis algorithm to identify distresses, the MDT Pavement Management personnel will manually field check the section(s) for each occurrence of distress (including distress severities).
- For each occurrence of a distress identified on the ground, the processed image will be checked. If the distress is properly identified, the occurrence will be recorded as 'passed'. If a distress on the section is not identified or not identified properly, the occurrence will be

recorded as 'failed'. If a distress is identified on the image but no distress is observed on the ground, a 'failed' occurrence will be recorded.

- When the calibration section or sections has been checked, the percentage of 'passes' will be checked against the target of 80% or better.
- Pathway Services will be informed of any major discrepancies in case any changes need to be made to the automated crack detection and analysis software.

Certification

To pass certification, the pavement condition data collection vehicle must pass Montana Department of Transportation's Inertial Profiler Certification Program. A SurPRO reference profiler creates the baseline profile for comparison against the Data Collection Vehicles.

- A certification site of 1128 feet in length is set up on asphalt pavement with an IRI ranging between 95 to 135 in./mile (medium-smooth roughness). The distance of the site is of survey precision. An additional site with IRI ranging between 30 to 75 in./mile (smooth) will be added beginning with the 2018 certification.
- A reference profile using the SurPRO is collected first using the following process:
 - First the SurPRO is calibrated for distance over a specified portion of the site.
 - After the distance calibration, a closed loop is collected on one of the wheel paths using the SurPRO. Then a total of 10 runs is collected on the same wheel path. This process is repeated on the remaining wheel path.
 - The 10 profiles from each wheel path is then sent to International Cybernetics (ICC) to combine all the profiles into one master reference profile.
- The Data Collection Vehicles collect 12 inertial profiles using the following process for data collection:
 - A block and bounce test shall be performed before collection
 - The DMI shall be calibrated over the 1128 ft. site
 - The speed at which the profilers collect the data shall be 45 mph
 - The data collection shall be auto-triggered using a photocell
- The master reference profile and 12 profiles from the Data Collection Vehicles are loaded into ProVAL for analysis using the Profiler Certification Module. Only 10 of the 12 inertial profiles will be needed for analysis.
 - The reference profile and each inertial profile shall be compared using an IRI filter (without the 250mm filter)
 - The IRI from each inertial profile being evaluated must be within 5% of the IRI from the reference profiler,
 - The mean cross-correlations of repeatability between each inertial profile must be at least 92%,
 - The mean cross-correlation of accuracy between each individual inertial profile and the reference profile must be at least 90%, and
 - The distance of each run must be within 0.2% of the actual length of the test section using the DMI.

- An official document is produced from the ProVAL analysis indicating a passing grade. Figure 3 below shows a summary of a passing grade.
- If the vehicle does not pass certification, the following will be completed:
 - Perform the bounce test and block test again.
 - Collect another 12 runs for comparison.
 - The manufacturer will be contacted for further instructions/recommendations on resolution of issues and to get the vehicle to meet/pass the criteria.

Analysis: Profiler Certification

Inputs

Maximum Offset (ft): 5.00
 Minimum Repeatability (%): 92
 Minimum Accuracy (%): 90
 Basis Filter: IRI (without 250mm Filter)
 Comparison Filter: IRI (with 250mm Filter)

Selections

File	Profiles	Basis	Run	Sample Interval
2017Master_All_LR_NOF	Left + Right	Yes	0	0.9999961
run3	Left + Right	No	1	1.4814470
run4	Left + Right	No	2	1.4814470
run5	Left + Right	No	3	1.4814470
run6	Left + Right	No	4	1.4814470
run7	Left + Right	No	5	1.4814470
run8	Left + Right	No	6	1.4814470
run9	Left + Right	No	7	1.4814470
run10	Left + Right	No	8	1.4814470
run11	Left + Right	No	9	1.4814470
run12	Left + Right	No	10	1.4814470

Summary Results

Accuracy (%)

Run	Left	Right
1	88.15	85.06
2	90.57	86.19
3	91.34	90.18
4	93.14	89.14
5	91.94	92.15
6	94.49	91.70
7	93.89	92.81
8	93.57	92.75
9	92.86	89.75
10	94.63	91.04

Statistics

Statistic	Repeatability - Left	Repeatability - Right	Accuracy - Left	Accuracy - Right
Comparison Count	45	45	10	10
% Passing	100.00	100.00	90.00	60.00
Mean	95.04	95.82	92.46	90.08
Minimum	92.48	92.94	88.15	85.06
Maximum	97.72	97.90	94.63	92.81
Standard Deviation	1.3	1.3	2.0	2.7
Grade	Passed	Passed	Passed	Passed

Figure 3: Passing Certification

Pavement Condition Data Collection Vehicle Verification

The pavement condition data collection vehicle conducts a weekly verification on the 5-mile baseline site created at the beginning of the season. The verification is performed either upon return from field on Thursday or on Monday morning prior to departure for collection.

- The weekly verification is one run. Tracking spreadsheet shown in Figure 4 below.
 - The tolerances for verification are: 5.7% for IRI and ± 0.05 inch for Rut
 - The Grade, Heading and Cross Slope are graphed and visually inspected
- In addition, a block and bounce test is performed each week:
 - A 1-inch block is measured by each wheel path laser, the difference between the measurement and the actual thickness shall be no greater than ± 0.01 in.
 - The bounce graphs are visually inspected for the following criteria:
 - Blue line should be as close to flat as possible ± 0.003 '
 - Red and black waves should be identical in amplitude.
- If the vehicle does not fall within the tolerances, the following will be completed:
 - The block and bounce tests will be redone.
 - An additional run is made of the verification site.
 - The manufacture will be contacted for further instructions/recommendations for resolution to get the vehicle to pass verification.
- The pavement condition data collection vehicle will be re-verified if any of the following occur:
 - The air pressure in the tires is changed, or tires have been changed.
 - The vehicle is realigned.
 - Any components of the vehicle's collection system have been changed/replaced.

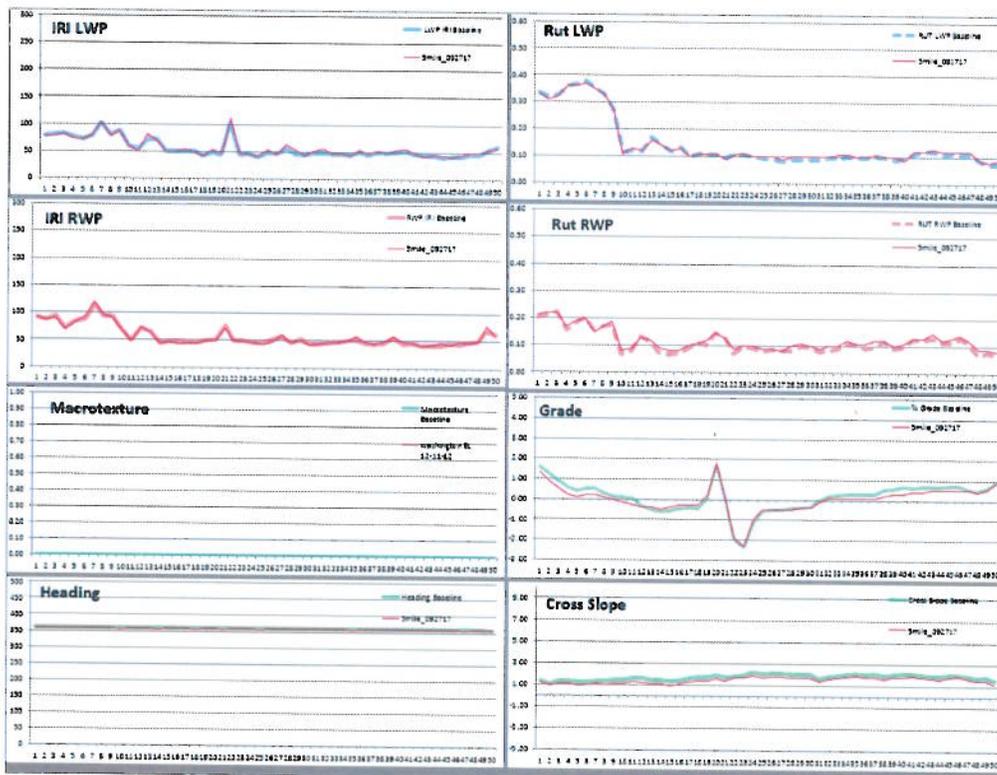


Figure 4: Weekly Verification

Initial Data QC Checks

Each week the pavement condition data collected will be uploaded to an office work station and backed up on an external hard drive. The following initial QC checks will be performed:

- Verify all image data is present by marking all records and finding first/last image. If no errors are returned, the images are ready for processing.
- Verify all sensor data is complete by processing raw files for left and right IRI. If no errors are returned, it's verified sensor data is complete and all raw files (IRI, Rut, texture, faulting and gyro) can be processed.
- After the raw files have been processed, each record is updated to get an average value for IRI and Rut.
 - IRI values should range from 50 to 200. Urban routes should range from 50 to 500.
 - RUT values should range from 0.05 to 0.50. Urban routes should range from 0.05 to 1.0.
- All images are inspected by virtually driving each collected segment for the following:
 - Start and End nodes are at the correct locations
 - Images are free of any debris (i.e. rain, bugs, etc.)
 - Image color is of satisfactory brightness/contrast
- Verify distress identification by comparison to random locations manually rated after running the collection data through the cracking algorithm.

QC Checks of All Distress Data for Final Acceptance and Reporting

At the end of the pavement condition data collection year the following QC will be performed:

- Populate averages in the database by updating summary.
- Drive all segments (at work station) to ensure starting/ending points for each record are correct. Fix as necessary and save .sec file. Use notes from van. If changes are made, may need to rerun the update summary.
- Check the quality on the images by viewing all images.
- All starting/ending points that need to be fixed will be fixed in the office.
- Run Auto Class (crack classification) on all previously processed data.

QC Checks for Auto Crack Detection and Analysis:

The cracking analysis will be run for the full mile and recorded at one-tenth mile increments. The images produced from the cracking analysis are checked for quality at the end of the season.

- 2% of all pavement types will be manually compared to the automated analysis.
- Two one-tenth mile sample sections from every 10 miles (2%) are selected at random to be checked for quality. Each collection week is loaded into an Excel spreadsheet designed to generate random samples and record/analyze each sample section.
- For each tenth-mile section, a Road Profile Analyst will review the section at the work station as shown in Figure 5. For each occurrence of a distress identified in the 3D image, if the distress is properly identified by the processing software, the occurrence will be recorded as 'passed'. If a distress on the image is not identified or not identified properly, the

occurrence will be recorded as 'failed'. If a distress is identified by the processing software but no distress is observed in the image, a 'failed' occurrence will be recorded.

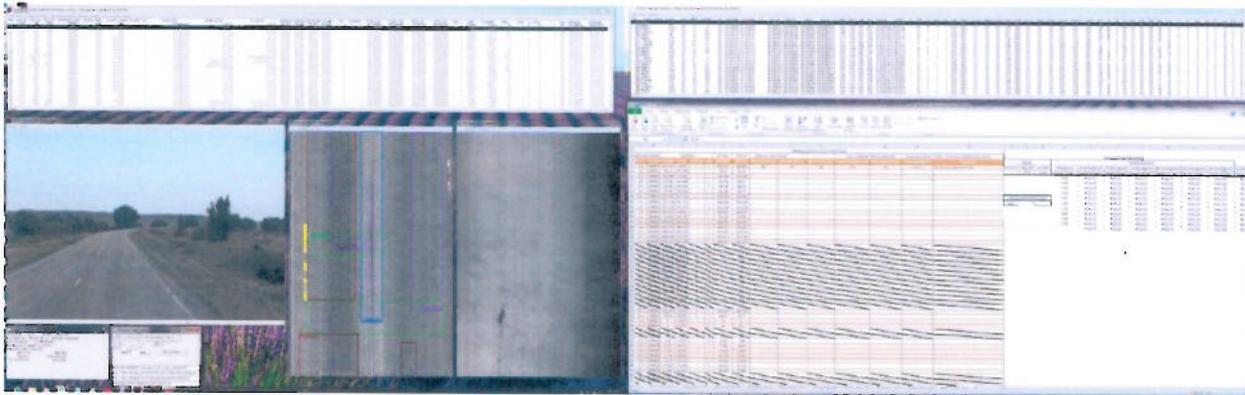


Figure 5: Workstation Distress Quality Check

Once a sample section is determined, every 3D image in that section is analyzed for the following criteria:

- Missed Crack: A crack that is visible on the 3D image but is not identified by the cracking analysis.
- Misidentified Crack: A crack that is identified by the cracking analysis but is classified incorrectly (i.e. Transverse crack being identified as concrete joint).
- Over/Under Distressed Crack: A crack that is classified for the incorrect severity (i.e. Transverse High instead of Transverse Low).
- For any crack occurrence that is correctly identified, the occurrence is recorded and marked as 'passed'.
- For sections failing to meet the 80 percent acceptance, a note is taken of the type(s) of occurrences along with a screenshot of the 3D image(s).
- When the sample sections have all been checked for the entire season, the percentage of 'passes' (as a proportion of all crack occurrences noted) will be checked against the target of 80%.
- Throughout the process, Pathway Services will be informed of any major discrepancies in case any changes need to be made to the automated crack detection and analysis software.

4. ACCEPTANCE

The focus of acceptance is to validate that deliverables meet the established quality standards. Following is a description of acceptance testing, the frequency to be performed, and corrective actions for items that fail to meet criteria.

Deliverable	Acceptance (Percent Within Limits)	Acceptance Testing & Frequency	Action if Criteria Not Met
IRI, rut depth, faulting, cross slope, longitudinal grade, GPS coordinates	95 percent compliance with standards	Weekly verification site testing. Global database check for range, consistency, logic, and completeness and inspection of all suspect data. Use of GIS for further inspection.	Reject deliverable; recalibrate and recollect data.
Distress ratings	80 percent	Global database check for consistency, logic, completeness. Two percent sample inspection upon delivery.	Contact vendor to resolve cracking algorithm.
Location of segment and segment begin point	98 percent	Plot on base map using GIS. Global database check of accuracy and completeness.	Return deliverable for correction.
Perspective, ROW and pavement images	98 percent of collection with not more than 5 consecutive images failing to meet criteria	Daily monitoring for clarity, brightness, bugs or raindrops during collection. Weekly inspection of collection video. Verification inspection upon delivery.	Reject deliverable; images must be re-collected. Contact vendor as needed.

5. QUALITY TEAM ROLES & RESPONSIBILITIES

The following identifies the quality-related responsibilities of the data collection team and lists specific quality responsibilities.

Team Role	Assigned Resource	Quality Management Responsibilities
Data Collection Manager	Pavement Mgt. Engineer; Unit Supervisor (1 FTE)	<ul style="list-style-type: none"> • Set quality standards, acceptance criteria, and corrective actions. • Approve each deliverable per quality standards. • Approve resolution of quality issues. • Assess effectiveness of QM procedures. • Recommend improvements to quality processes. • Monitor schedule adherence. • Supervise measurement of control and verification sites. • Supervise acceptance checks. • Assure practice of QC measures in QM plan. • Assure proper protocols used. • Assure training plan addresses all personnel skill levels. • Assure correction of all quality issues and changes in procedures as needed. • Prepare QM report.

Team Role	Assigned Resource	Quality Management Responsibilities
Data Collection Lead, QC	C.E. Specialist (1 FTE)	<ul style="list-style-type: none"> • Communicate weekly with Pavement Management Unit Supervisor on data collection progress. • Submit acceptance exceptions log to data collection team. • Establish reference values with data collection team. • Monitor resolution of quality exceptions reported to data collection team. • Assure deliverables meet broad set of data quality requirements. • Observe and maintain records of control, and verification site testing. Analyze and document results. • Perform data and video acceptance checks and document results. • Assure performance of all quality audits and reporting of all data quality exceptions using Collection log. • Perform and document final deliverables quality review. • Compile documentation of all QC activities. • Document quality audits of uploaded and processed data. Report any problems using Collection log. • Document testing of Road Profile Analysts on initial control site calibration. • Perform and document quality audits, including intra- and inter-rater checks. Report any problems using Collection log.

Team Role	Assigned Resource	Quality Management Responsibilities
Data Collection Staff	Road Profile Analysts (3 FTE)	<ul style="list-style-type: none"> • Perform GIS checks and document results. • Maintain acceptance log and submit quality exceptions to data collection lead. • Perform daily and/or periodic equipment start-up checks, tests, inspections, and calibrations. • Perform daily review of data logs and video samples. • Assure real-time monitoring of data and video quality. • Assure performance of weekly control, and verification site testing. • Assure documentation of all field QM activities and reporting of any problems using Collection log. • Perform and document initial rater training and assure raters adequately trained in protocols. • Perform and document checks of total mileage, segment lengths, and comparison with master route file. • Assure and document GIS checks of segment location and completeness. • Perform and document initial Road Rater training and assure raters adequately trained in protocols. • Perform retraining as needed. • Perform and document quality audits, including intra- and inter-rater checks.

6. QUALITY REPORTING PLAN

The data collection lead will monitor quality through QC activities and report data quality exceptions as part of weekly status reporting, or more frequently if conditions warrant. Quality is monitored through data processing and reported to the data collection team as soon as quality issues are discovered.

The Collection Log is used by the data collection team to itemize, document, and track to closure items reported through Collection QC process.

COLLECTION LOG H12-175 (SOUTH) 2019
X:\Pavemgmt\DATA_COLLECTION\AUTOMATED_VANS\02_COLLECTION_VEHICLES\00_TEMPLATES_FORMS\COLLECTIONLOG_PRINT.XLSX

DATE	SEC FILE	CORRIDOR	FROM (MP)	TO (MP)	I or D	LANE #	SET #	# OF NODES	NODE v	MINUTE v	DATA RESTORATION / EDITING DATABASE NOTES

The data collection team will keep the Pavement Management Engineer informed of weekly progress. The team will also keep the Pavement Management Engineer informed of any major QC issues or equipment issues. The Pavement Management Engineer will try and resolve any issues that the data collection team is unable to keep data collection going as efficiently as possible.

Final QM Reporting

Data Collection Team – Once the season collection is complete, the data collection team provides the Collection logs, a summary of schedule (including any deviations), the collection vehicles and personnel assigned to each, documentation of equipment calibration and maintenance, results of all control and verification spreadsheet, and documentation of other problems encountered (not listed on the Collection log) and corrective actions taken.

Pavement Management Engineer – Upon acceptance of the final database and all other deliverables, the Pavement Management Engineer prepares a draft Quality Management Report. The report summarizes scope and schedule, description of control and verification site testing (including reference values and analysis of results), description of all global and sampling tests performed and the results, and recommendations for improvement.

7. AGENCY & DATA COLLECTOR QM PLAN ACCEPTANCE

Quality Management Plan accepted by the Pavement Analysis Engineer:



Jim Davies, P.E.
MDT Pavement Analysis Engineer

Date: 4-24-18