COLORADO
Department of Transportation

2022

TRANSPORTATION ASSET MANAGEMENT PLAN

DECEMBER 2022

CONTENTS

EXECUTIVE SUMMARY

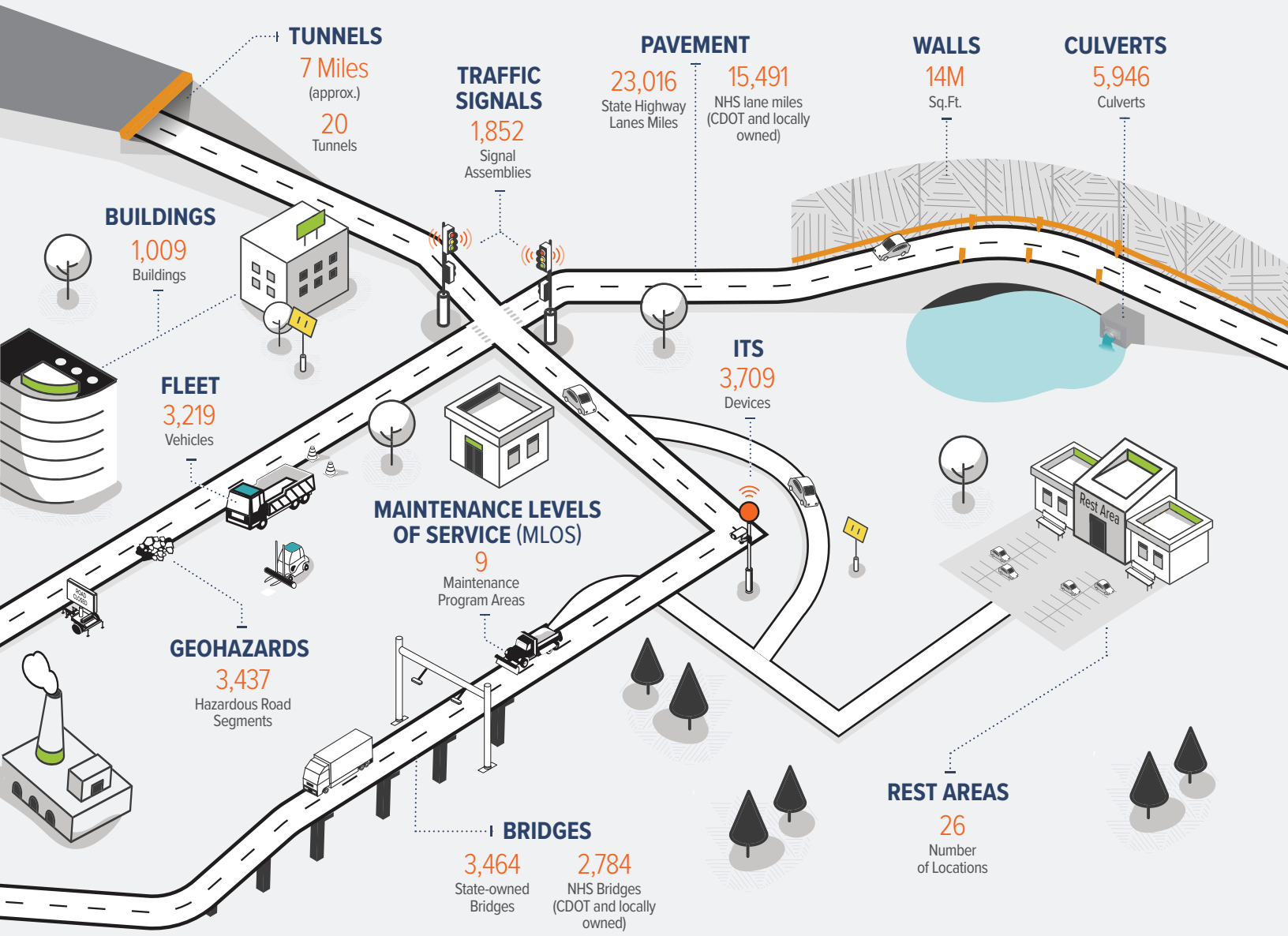
Colorado's transportation infrastructure is as diverse and dynamic as the state itself. Bridges span majestic canyons and rivers. Miles of pavement climb and descend the mountainous landscape. And culverts, retaining walls, rockfall fences, traffic signals, cameras, wireless technology, and other assets make the whole system work.

CDOT's 2022 Transportation Asset Management Plan (TAMP) describes how the Department will manage these assets effectively. In doing so, the plan will enable CDOT to support, maintain, and expand the transportation system, and to play a proactive role in the economic vitality of the state and the quality of life of its people.

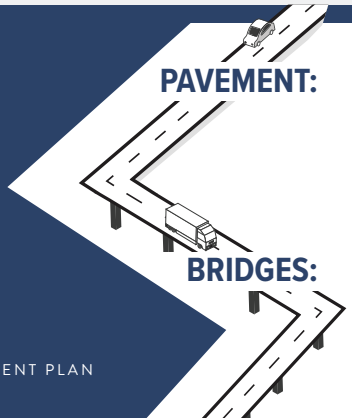
WHERE WE ARE AND WHAT WE DO

CDOT's Transportation Asset Management (TAM) program comprises 12 asset programs, including pavement, bridges and many more. Each program is vital to achieving CDOT's mission of providing the best multimodal transportation system that effectively and safely moves people, goods, and information. The programs also advance asset management goals by preserving infrastructure condition at a least life-cycle cost. **Figure ES-1** illustrates the function and number of assets in each program, and the text that follows describes the benefits of each asset type.

Figure ES-1 *Summary of CDOT's Assets*



CDOT's asset programs provide a range of benefits to Colorado:



PAVEMENTS AND BRIDGES. Pavement and bridge assets reach every corner of the state—traversing mountains, spanning lakes and rivers, and connecting Coloradoans to seven neighboring states. Pavements and bridges form the backbone of the highway system and are the system's highest-valued assets in terms of replacement cost.

BUILDINGS. Buildings provide facilities to safely store and maintain essential vehicles, equipment, and supplies. Buildings also provide offices for administrative staff and laboratories for technicians.

CULVERTS. Culverts are structures that convey water beneath the roadway or carry the roadway over obstacles. These assets are crucial to providing drainage during storm events, enabling safe traffic flow over waterways, preventing soil erosion, and even providing safe passage for wildlife.

FLEET. CDOT's diverse fleet of vehicles and roadway equipment supports the safety and mobility of the traveling public and the preservation of Colorado's highway system by facilitating safe, timely, and efficient roadway operations, repairs, and improvements.

GEOHAZARDS. The Geohazards program identifies and manages geologic risks to Colorado's transportation system—such as from falling rocks, landslides, and sinkholes—by implementing risk-reducing treatments on strategic highway segments and corridors.

INTELLIGENT TRANSPORTATION SYSTEMS. Intelligent Transportation Systems (ITS) assets advance the safety and mobility across Colorado's diverse landscape by processing and sharing information. ITS assets enable calls for emergency services on secluded mountain passes, use cameras to monitor traffic and ease congestion, deploy messages via signs to assist travelers in adverse weather conditions, and provide broadband access to connect communities.

MAINTENANCE LEVELS OF SERVICE. Maintenance Levels of Service (MLOS) provides major operational services—notably snow and ice removal from roadways—as well as preservation and maintenance services for pavement, bridges, tunnels, culverts, walls, rest areas, and more. MLOS also manages many safety- and traffic-related assets, such as signs, guardrails, pavement markings, delineators, roadway lights, crash/energy attenuators, and fences.

REST AREAS. Rest areas provide an oasis where travelers can safely pull over to take a break, use the restroom, and get information on local attractions. Rest Areas support the safety of the traveling public and attract tourism to help support the state's economy.

SIGNALS. Traffic signals are vital to helping travelers safely navigate Colorado's diverse highway network, ensuring that vehicles avoid collisions, easing traffic congestion, protecting bicyclists, and allowing pedestrians to safely cross streets.

TUNNELS. Tunnels significantly shorten the distance and time of travel through Colorado's mountainous terrain. They ensure optimum protection for the surrounding environment and landscape by minimizing interference with surface life, as compared to deep cuts or longer routes.

WALLS. Walls help ensure roadways are stable across Colorado's rugged landscape and fit into the natural environment. CDOT's walls retain embankments, support bridges, and serve as physical barriers to block highway noise.

WHAT ARE OUR TOP RISKS?

CDOT uses an enterprise-wide approach to manage risks, from the Department-wide level down to the asset level, incorporating four levels of risk management:

- Enterprise (Strategic, Corporate)—Threats that affect the agency's mission and vision, as well as the results of the asset-management program.
- Program (Business Line)—Threats that affect CDOT's ability to deliver projects and meet targets within a program.
- Project—Threats that affect the cost and schedule to deliver projects throughout the agency.
- Activity—Threats that affect ongoing functions that support programs, projects, and asset classes.

Each asset class maintains its own risk register. **Table ES-1** shows CDOT's top enterprise risks.

Table ES-1 *Top 10 Enterprise Risks at CDOT*

Threat/Opportunity	Risk Statement	Risk Management Strategy
Flood	There is a risk that flooding occurs, leading to asset/route damage that causes mobility and safety impacts as well as increased asset management cost.	Treat by implementing design standards; following agency continuity of operations plan; maintaining incident command center management structure; maintaining an Office of Emergency Management (OEM). Use tools and processes developed under the resilience program to identify high risk assets and corridors for focused analysis.
Post-Fire Debris Flow	There is a risk that post-fire debris flow occurs, leading to asset/route damage that causes mobility and safety impacts as well as increased asset management cost.	Treat by maintaining an office of OEM, as well as through landscaping, erosion control, jersey barriers and other practices.
Funding Uncertainty	There is a risk of funding changes leading to increased/reduced investment that causes improved/diminished asset management outcomes.	Tolerate/take advantage of—manage on per event basis.
Geohazards	There is a risk of geotechnical failure that causes mobility and safety impacts as well as increased asset management cost.	Treat by maintaining geohazards program and robust geohazards-management plan.
Cost Uncertainty	There is a risk that price escalation occurs, leading to unsustainable costs and thereby limiting the ability to deliver organizational objectives.	Treat by bid process (e.g., bid rejection), re-scoping projects, price hedging, and by hedging materials; then tolerate.
Fire	There is a risk that fire occurs, leading to asset/route damage that causes mobility and safety impacts as well as increased asset management cost.	Tolerate in the case of wildfires; and treat by tunnel fire-suppression systems and bridge-design standards, etc. Use tools and processes developed under the resilience program to identify high risk assets and corridors for focused analysis.
Missing Infrastructure Targets for National Performance Measures	There is a risk that CDOT is not able to meet PM2 condition minimum requirements, leading to restricted funding that limits the agency's ability to meet its objectives.	Treat by implementing formal asset management program. Use tools and processes developed under the resilience program to identify high risk assets and corridors for focused analysis.
Snow (Avalanche)	There is a risk of avalanche that causes mobility and safety impacts as well as increased asset management cost.	Treat by maintaining a Winter Operations Program. Use tools and processes developed under the resilience program to identify high risk assets and corridors for focused analysis.
Cybersecurity	There is a risk that a cyber-attack occurs, leading to a reduction in CDOT ability/effectiveness, which results in reduced mobility and safety outcomes.	Transfer to Governor's Office of Information Technology. Treat by maintaining firewalls; virus protection software; training employees on cybersecurity.
Staffing: Attrition	There is a risk that CDOT suffers from a shrinking workforce, leading to loss of institutional knowledge that reduces efficiency and effectiveness.	Treat by documenting policies and procedures.

Figure ES-2 Summarizes how CDOT's assets are currently performing. Any additional performance measures for assets excluding pavements and bridges can be found within the individual asset plans in the Asset Plan Appendix.

Figure ES-2 *Current Performance of CDOT's Asset Programs against PD 14.0 Targets*

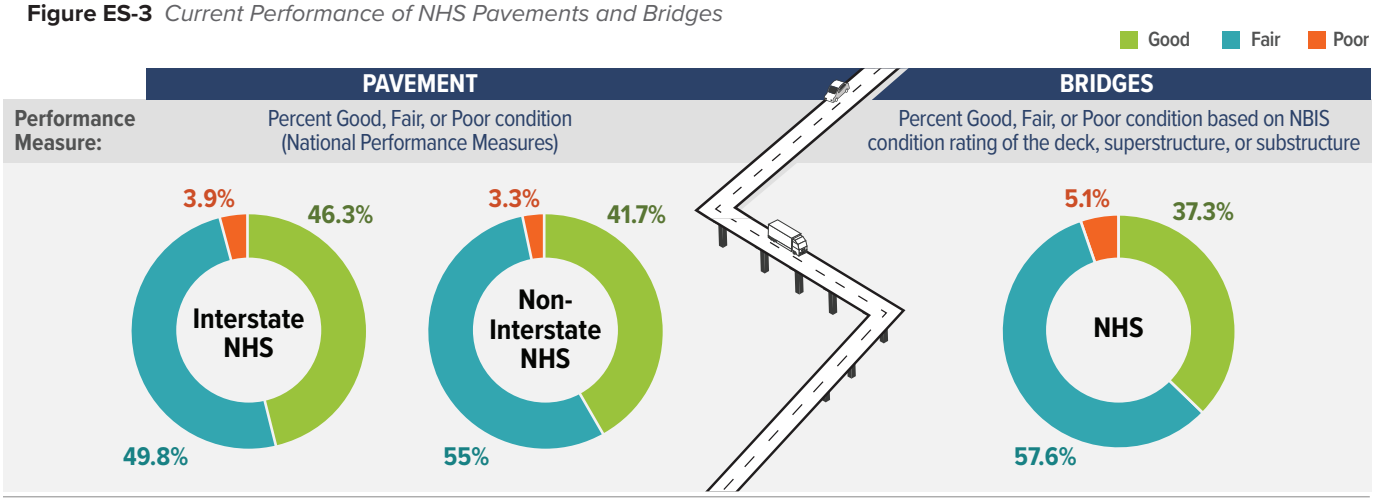
NATIONAL PERFORMANCE MEASURES—CURRENT PERFORMANCE

The Federal Highway Administration (FHWA) requires state departments of transportation (DOTs) to provide an asset-management plan that, at minimum, addresses pavements and bridges on the National Highway System (NHS).

Figure ES-3 summarizes the current condition of pavement and bridges on the National Highway System, according to FHWA's National Performance Measures (NPMs). While the federal measures for pavement quality (Good, Fair, and Poor) incorporate some of the same quality indicators as CDOT's internal pavement measures (High, Moderate, and Low Drivability Life), the measures are not comparable. Meanwhile, CDOT's primary measures for evaluating bridge condition (Good, Fair, and Poor) are identical to the federal measure.

The NHS includes Interstate and certain non-Interstate highways. CDOT owns and maintains all Interstate pavement. While the Department owns a majority of the non-Interstate NHS, certain municipalities and counties own stretches as well.

Figure ES-3 *Current Performance of NHS Pavements and Bridges*

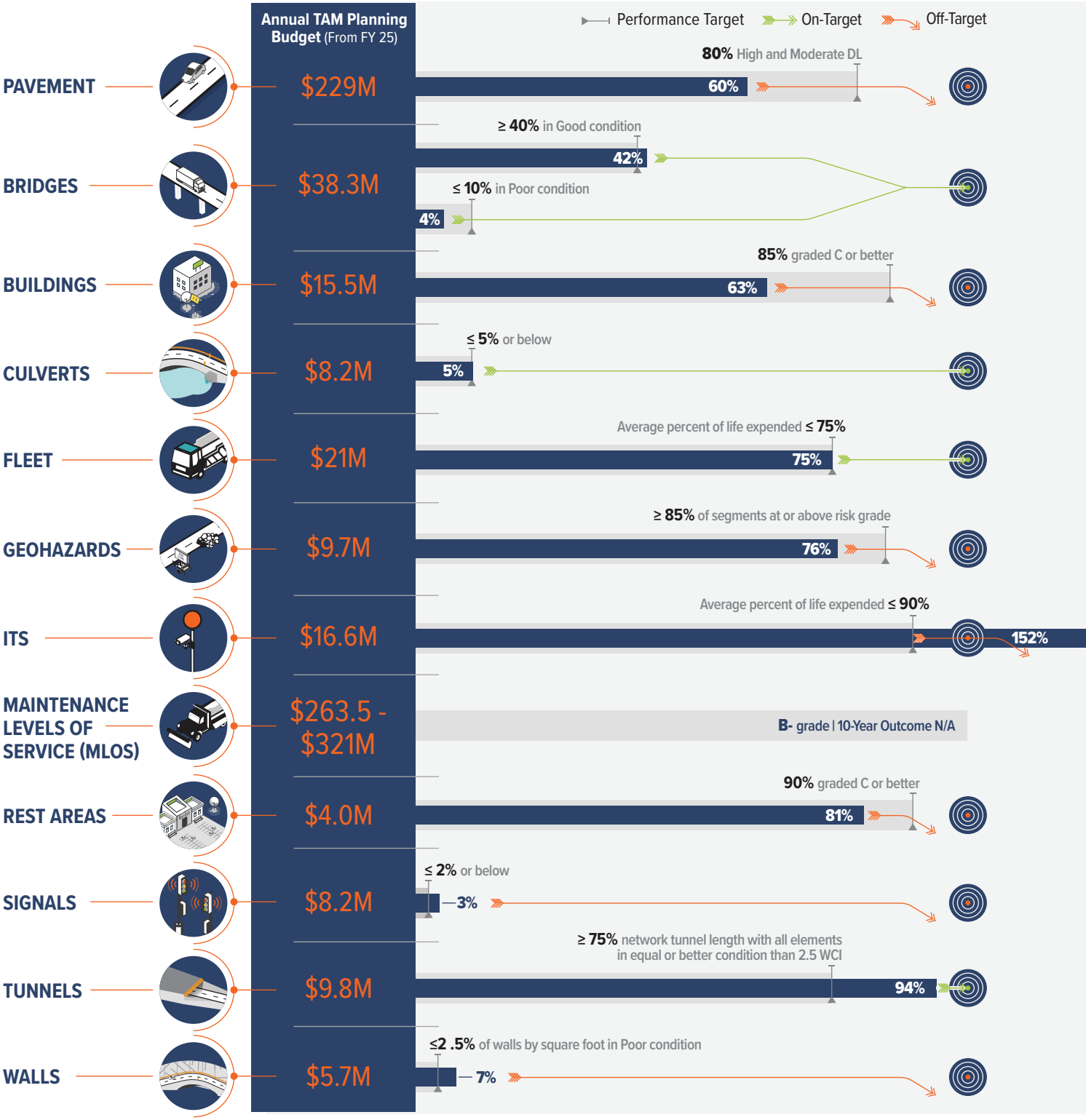


WHERE WE ARE GOING

The financial plan presented in this TAMP (and the Asset Plan Appendix) provides sufficient funding for four of CDOT's 12 asset classes to meet the Department's internal performance targets within the 10-year analysis period.

Bridges, Culverts, Fleet, and Tunnels will meet their targets, while the remaining asset classes require additional funding. The majority of that additional funding would be for pavements, buildings, geohazards, ITS, and walls. **Figure ES-4** summarizes projected performance for CDOT's 12 asset programs over the 10-year TAMP analysis period.

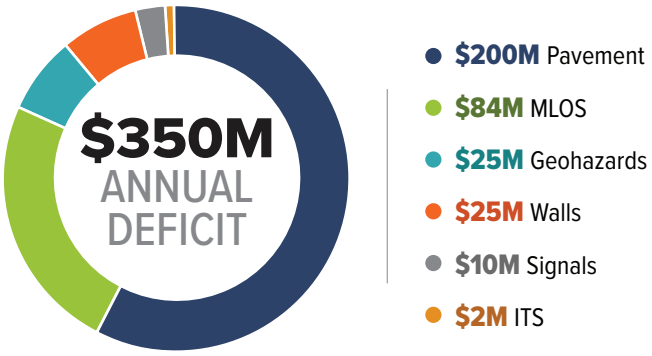
Figure ES-4 *Projected 10-Year Performance of CDOT's 12 Asset Classes*



CDOT'S ASSET MANAGEMENT FUNDING DEFICIT

CDOT's asset management funding is insufficient to maintain current conditions and meet long-term performance goals. The Department forecasts that about **$350 million** per year above current asset-management funding would be required to meet the primary internal performance targets in 10 years. Bridges, Culverts, Fleet, and Tunnels are forecast to meet their targets at current funding levels, while the remaining asset classes require additional funding. Two asset classes—Pavement and Maintenance Levels of Service (MLOS)—make up about 80 percent of the **$350 million** deficit. Readers should note that deficit estimates may change significantly as metrics evolve, targets are adjusted, and models are refined.

Figure ES-5 *Additional Funding per Year Required to Meet Asset* Performance Targets in 10-Year Timeframe*



**For all CDOT's asset classes except buildings and rest areas.*

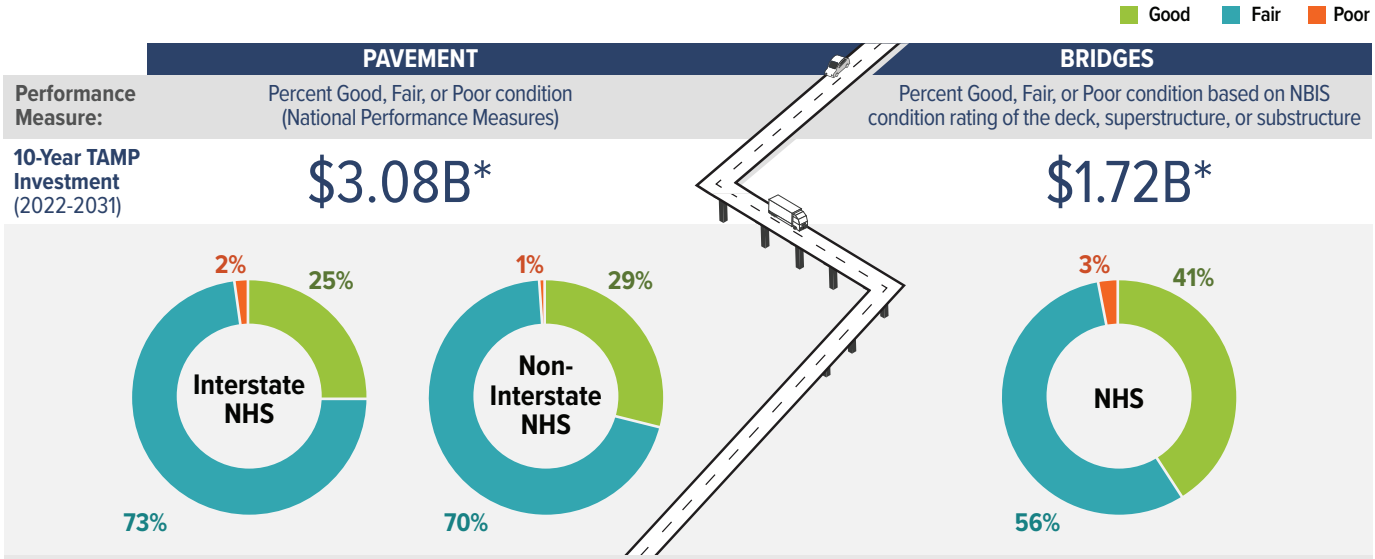
PAVEMENT—PROJECTED PERFORMANCE

Over this plan's 10-year timeframe, State Highway System pavement in High and Moderate condition, based on CDOT's Drivability Life metric, is forecast to fall before it begins to recover. This is because a large proportion of pavement (30 percent of total lane miles) is expected to move from Moderate to Low condition over this time period. However, a key strategy of CDOT's pavement program is to preserve pavements with High and Moderate Drivability Life, which will improve long-term outcomes. This strategy will enable CDOT to come close to meeting the Department's internal performance target within a 15-year timeframe. About 79 percent of pavement is expected to reach High or Moderate condition by 2036, just shy of the 80 percent target.

NATIONAL PERFORMANCE MEASURES—PROJECTED PERFORMANCE

Figure ES-6 summarizes the projected future performance for pavement and bridge assets on the National Highway System (NHS).

Figure ES-6 *Projected 10-Year Performance of NHS Pavements and Bridges*



The charts above show that the percentages of poor bridges and poor pavement are forecast to decline from what is shown in Figure ES-3, but challenges lie ahead in managing the aging asset population. For example, the Department faces an extensive inventory of poor bridges in the Denver Metro area, and the large statewide inventory of fair structures will require high levels of consistent maintenance and investment to prevent them from falling into poor condition.

* For State Highway System, not just NHS. Includes maintenance levels of service. Bridge number also includes Statewide Bridge and Tunnel Enterprise.

HOW WE WILL GET THERE

CDOT is committed to managing the state's transportation infrastructure to the highest standards possible, for as long as possible, and has long embraced asset management principles as standard business practice.

Going forward, CDOT will continue to guide investment decisions to maintain assets in a state of good repair for the least practicable cost. To do so, CDOT's asset-management program will leverage recent and updated policies that drive asset performance, including by establishing performance measures and targets. The program also will continue to employ its comprehensive set of asset-management practices and decision-support tools.

ASSET MANAGEMENT POLICIES

The Transportation Commission adopted the updated Policy Directive 14.0 in 2020, which included revised goals that measure the success of the Department's efforts to improve asset management, safety, and mobility, as wells as support the national goals for surface transportation. PD 14.0 encourages the Transportation Commission to direct funds to budget categories that support the accomplishment of the directive's performance targets.

In January 2021, Transportation Commission adopted Policy Directive 1609.0, which requires the Department's 12 asset classes to maintain an inventory, condition information, performance metrics, and performance targets. This formally re-affirmed CDOT's commitment to asset management across all asset classes by mandating the collection, development, and sustainment of foundational asset data.

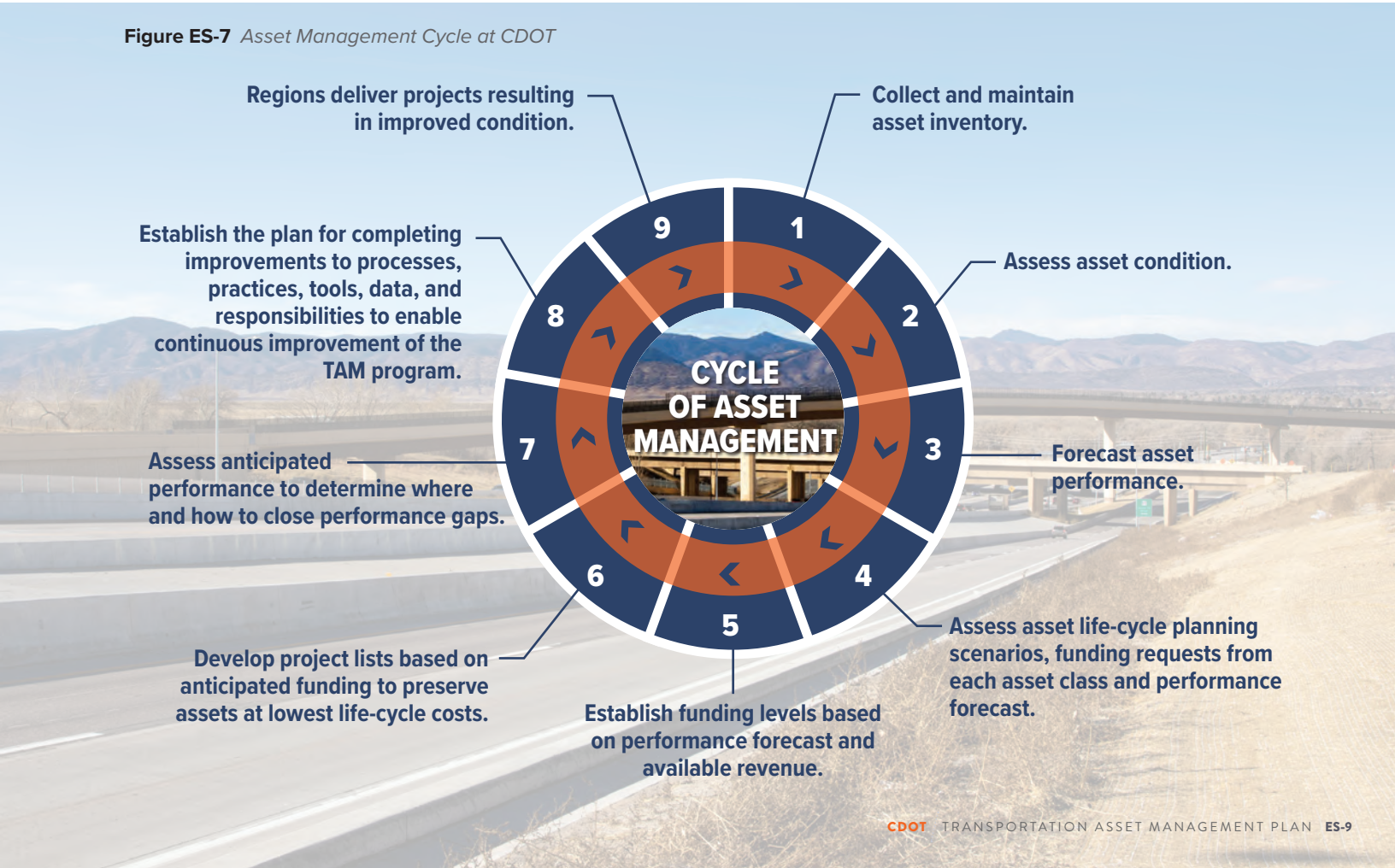
ASSET MANAGEMENT PRACTICES

CDOT's established asset management cycle defines how the Department makes decisions about its assets, including considering a range of life-cycle management approaches that reflect the criticality of different assets to the asset management, safety, and mobility outcomes the Department wants to achieve. **Figure ES-7** illustrates CDOT's asset management cycle.

ASSET MANAGEMENT DECISION-SUPPORT TOOLS

CDOT's Asset Investment Management System (AIMS) is modeling software that uses past performance data, deterioration assumptions, and treatment information to predict the future condition of an asset class under

Figure ES-7 *Asset Management Cycle at CDOT*



varying funding levels. The software also recommends the most cost-effective asset treatments to achieve the Department's performance goals for each asset class.

By comparing forecasted performance under different funding levels, the software helps the TAM Program determine how much funding an asset class should receive. AIMS helps to ensure that the Department's assets are used most efficiently, enhancing asset functionality by achieving the greatest benefit at the lowest cost while maximizing the asset's lifespan.

CONTINUOUS IMPROVEMENT

CDOT intends to leverage this TAMP to advance processes that optimize asset investments to achieve Department performance goals. To that end, the TAM Program intends to:

- Strengthen the alignment of asset management processes with overarching CDOT goals.
- Satisfy federal requirements detailed in 23 U.S.C. 119(e)(1), MAP-21 § 1106.
- Establish and document asset management processes and guidance without limiting flexibility.
- Communicate the importance of asset management to key audiences.
- Promote internal communication, understanding, and collaboration across asset types and between CDOT's Headquarters and Regions.
- Promote more uniform processes and analysis approaches across asset programs to advance CDOT's ability to analyze and consider tradeoffs.
- Expand the reach of asset management principles and needs within CDOT.
- Establish performance measures and the desired state of good repair for pavement and bridges on the Interstate and National Highway System.

Planned improvements to the TAM program include the following:

	IMPROVEMENT AREA	OUTCOME ACHIEVED
SHORT-TERM	**Treatment-delivery tracking.** Improve ability to track planned asset treatments from planning stage through project delivery, ideally through a transportation project-management system such as PMWeb.	Improves understanding of the link between asset-management treatment selections and STIP project delivery.
SHORT-TERM	**Risk integration.** Integrate Risk and Resilience Program within the Performance and Asset Management Branch and continue to implement risk practices across the Department.	Improves risk and resilience communication and practices. Leads to more proactive management of threats.
SHORT-TERM	**Process documentation.** Build on the recent Policy Directive 1609.0, which documents core asset-management practices, with a new procedural directive and other documentation.	Manages risks from staff turnover and provides a starting point for further enhancement.
SHORT-TERM	**Bridge and tunnel asset management.** Improve life-cycle planning for these assets and further develop the recently created tunnels portion of the Bridge and Tunnel Enterprise.	Minimizes life-cycle costs and better prioritizes investments.
MID-TERM	**Extreme weather and resilience.** Enhance current approaches for integrating as part of lifecycle cost and risk management analyses.	Improves the ability for infrastructure to handle weather and climate threats.
MID-TERM	**Life-cycle planning.** Continue to enhance analyses from assets' model (AIMS). For example, include a broader range of work types within the model.	Improves ability to estimate future funding needs and to prioritize asset treatments.
LONG-TERM	**Tradeoff analyses.** Improve ability to perform multi-objective decision analysis (MODA) and cross-asset optimization for asset management decision making.	Improves understanding of alternative funding strategies.

CDOT'S COMMITMENT TO COLORADO

Dear reader,

I am pleased to present the Colorado Department of Transportation's 2022 Transportation Asset Management Plan (TAMP).

CDOT's previous asset-management plan was approved by the Federal Highway Administration (FHWA) in 2019. This update goes far beyond that document and plan requirements in 23 CFR 515.9. Not only does the plan include required pavement and bridge assets, its appendices include plans for the 10 other assets in our comprehensive Transportation Asset Management (TAM) Program.

As shown in the following pages, CDOT employs an asset-management approach across all asset types—roads, bridges, tunnels, culverts, and many more—to minimize risks, disruptions and life-cycle costs associated with Colorado's highways. At the same time, our asset-management approach maximizes asset performance and supports economic and recreational opportunities in all corners of the state.

The state of Colorado in recent years has demonstrated its commitment to asset management by passing Senate Bills 260 and 267. Over the next five years these sources will contribute more than $2 billion to highway projects in CDOT's 10-Year Plan. In addition to funding strategic expansion projects, the 10-Year Plan serves as a parallel funding mechanism to our base asset-management program to maintain existing roads and bridges. SB-260 also generates fees to expand the Statewide Bridge and Tunnel Enterprise beyond its historical mission of improving poor bridges to caring for critical tunnels, such as the Eisenhower-Johnson Memorial Tunnel.

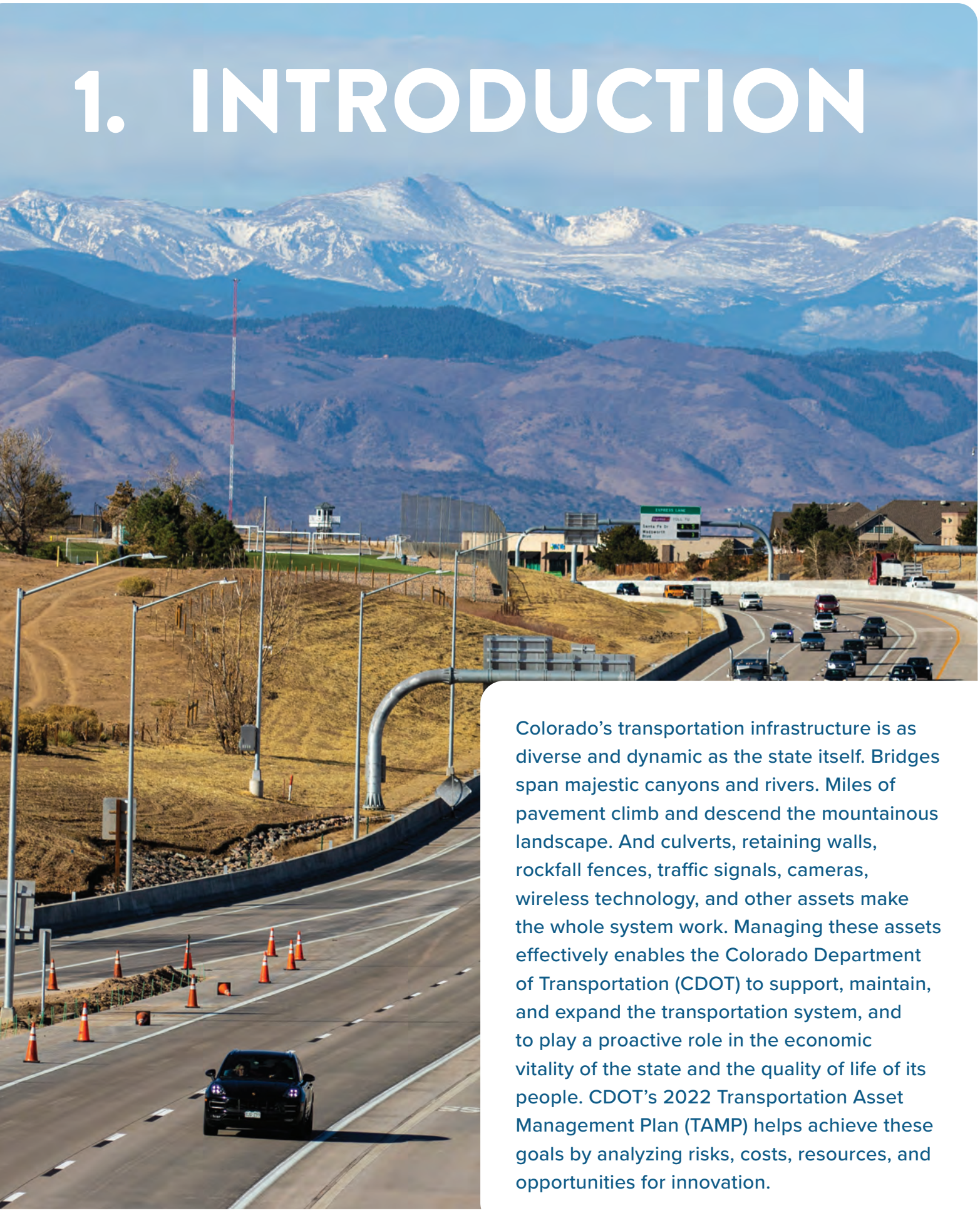
Recently adopted policy directives at CDOT further demonstrate the commitment of the Department to embed asset management and risk and resilience into the work we do every day. This TAMP reinforces that commitment by documenting how we use data and predictive tools to recommend the most cost-effective mix of maintenance and preservation activities, and to forecast future performance. Moreover, the TAMP shows how we are allocating funding to achieve internal performance targets, as well as targets for National Performance Measures. Finally, the TAMP describes how we manage threats at all levels and how we plan to improve asset management going forward.

With this plan, CDOT reaffirms its commitment to asset management as a critical tool in delivering our mission, improving the economic vitality of the state, and enhancing the quality of life of all Coloradans.

Best regards,

Shoshana M. Lew
CDOT Executive Director

1. INTRODUCTION



Colorado's transportation infrastructure is as diverse and dynamic as the state itself. Bridges span majestic canyons and rivers. Miles of pavement climb and descend the mountainous landscape. And culverts, retaining walls, rockfall fences, traffic signals, cameras, wireless technology, and other assets make the whole system work. Managing these assets effectively enables the Colorado Department of Transportation (CDOT) to support, maintain, and expand the transportation system, and to play a proactive role in the economic vitality of the state and the quality of life of its people. CDOT's 2022 Transportation Asset Management Plan (TAMP) helps achieve these goals by analyzing risks, costs, resources, and opportunities for innovation.

1.1 OVERVIEW

CDOT is committed to managing the state's transportation infrastructure to the highest standards possible, for as long as possible. The Department understands that in a time of constrained budgets, effective management of transportation assets is a priority. Recognizing this imperative, the U.S. Congress codified asset management principles into law in 2012 as part of the Moving Ahead for Progress in the 21st Century Act (MAP-21). The law required all states to develop and implement risk-based transportation asset management plans (TAMPs). The 2015 Fixing America's Surface Transportation (FAST) Act reaffirmed this requirement, and in October 2016 the Federal Highway Administration (FHWA) issued regulations spelling out the requirements for TAMP submissions. In 2021, Congress continued its focus on transportation asset management in the Infrastructure Investment and Jobs Act (IIJA), including a historic increase in funding for infrastructure and for improving resilience.

CDOT's 2022 TAMP aligns with federal requirements, as well as with the Department's mission and its Transportation Commission Policy Directive 14.0. (PD 14.0), Policy Guiding Statewide Plan Goals and Objectives. The goals for PD 14.0 and CDOT's *2045 Statewide Transportation Plan* align with the FAST Act's nationally stated goals, and the PM1 (safety), PM2 (bridge and pavement condition), and PM3 (system performance, freight, congestion mitigation and air quality [CMAQ]) National Performance Measures. Each PD 14.0 goal area—asset management, safety, and mobility—contains multiple performance measures and objectives that allow CDOT's internal stakeholders to evaluate statewide efforts, how they align with the overall direction of the agency, and how they support the achievement of National Performance Measures. The Department's TAMP also integrates with performance objectives set forth in related policies and documents, such as CDOT's *Greenhouse Gas (GHG) Pollution Reduction Roadmap*, the *CDOT Performance Plan*, and the *Governor's Wildly Important Goals* (WIGs). For example, the safety goal area statement and objectives reflected in this TAMP align with the *Colorado Strategic Transportation Safety Plan* (STSP).

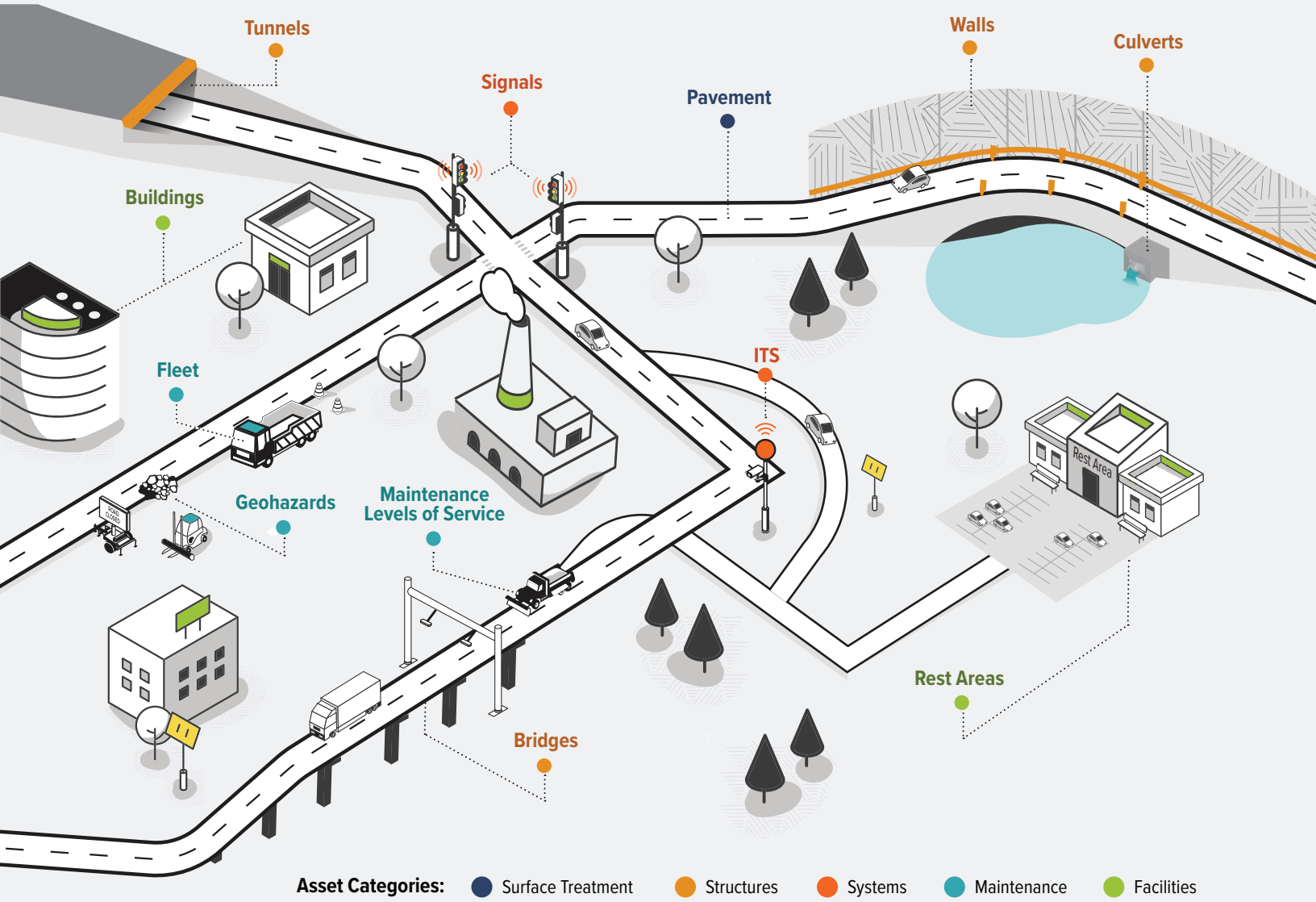
The measures and targets in PD 14.0 help establish a performance-based Transportation Asset Management (TAM) Program at CDOT and encourage a comprehensive, data-driven approach. In addition to PD 14.0, CDOT's new Policy Directive 1609.0 (PD 1609.0), Transportation Asset Management, ensures the Department will stay committed to key asset-management practices—such as maintaining inventories and asset models.

The American Association of State Highway and Transportation Officials (AASHTO) defines transportation asset management as "a strategic and systematic process of operating, maintaining, upgrading, and expanding physical assets effectively through their life cycle. It focuses on business and engineering practices for resource allocation and utilization, with the objective of better decision-making based on quality information and well-defined objectives."

CDOT's approach aligns with the focus of the IIJA to plan and make improvements to advance resiliency. It sets the foundation for enhancing CDOT's approach towards considering extreme weather events and resilience in life-cycle planning and investment strategies. This includes implementation of CDOT's Policy Directive 1905.0 (PD 1905.0), Building Resilience into Transportation Infrastructure and Operations, adopted in 2018. The directive positions CDOT to deliver on FHWA's emphasis on resilience by directing the Department to incorporate the concept into all aspects of CDOT business, including strategic decisions about assets and operations.

This TAMP prepares Colorado's transportation infrastructure for the future by analyzing risks, costs vs. needs, resources, and innovation opportunities across all 12 of its asset classes. In addition to raising awareness of the asset management process and objectives throughout the Department and its Engineering Regions, the plan communicates CDOT's commitment to asset management to other transportation stakeholders and to the public. **Figure 1** presents the 12 asset classes managed within CDOT's TAM Program.

Figure 1 *CDOT's 12 Asset Classes*



Pavement and bridge assets are the primary focus of this TAMP, as required by FHWA. However, within the main document, summary information will be provided about all 12 asset classes. "Asset plans" for all non-pavement/ bridge assets are included in the Asset Plan Appendix to this TAMP.

1.2 TAMP VISION STATEMENT

The vision of CDOT's 2022 TAMP is to advance processes that optimize asset investments to achieve Department performance goals. The plan helps prepare Colorado's transportation infrastructure for the future by analyzing risks, costs, resources, and opportunities for innovation. To accomplish this vision, the plan focuses on:

- Aligning asset management processes with overarching CDOT goals.
- Satisfying federal requirements for asset management plans.
- Establishing and documenting asset management processes and guidance without limiting flexibility.
- Communicating the importance of asset management to key audiences.
- Promoting internal communication, understanding, and collaboration across asset types and between CDOT's Headquarters and Regions.
- Promoting more uniformity among assets and augmenting CDOT's ability to consider tradeoffs.
- Expanding the reach of asset management within CDOT.

1.3 CONTINUOUS IMPROVEMENT SINCE 2019 TAMP

CDOT has made several improvements to its TAM Program since the previous TAMP was submitted in 2019. As shown in **Figure 2**, these changes have focused on better integration with functional areas, such as CDOT's Risk and Resilience Program, and enhancement of analyses, communication, and program management.

Figure 2 *Improved Areas Since 2019 TAMP*

IMPROVED AREA	OUTCOME ACHIEVED
The Transportation Commission reaffirmed and adopted PD 14.0 in November 2020, with revised performance measures and objectives.	Linking performance management across the areas of safety, asset management, and mobility in accordance with MAP-21.
CDOT has moved the Resilience Program to within the Performance and Asset Management Branch (PAMB).	Improved integration of risk, resilience, performance, and asset management.
CDOT has improved and expanded its asset management practices, including expanding documentation of treatment types to include additional asset classes, advancing asset modeling capabilities, and refining the Pavement National Performance Measure model.	Enhanced life-cycle planning analysis and forecasting of pavement National Performance Measures.
CDOT has updated its budget-setting process. This includes separating it from a larger program meeting and providing the Oversight Committee with "scenarios"—potential budget distributions for each asset.	The TAM Oversight Committee has more explicit budget requests so the committee knows exactly what each asset class is asking for, how the money will be used, and what they would use the money for.
Addition of Regional Transportation Directors to the TAM Oversight Committee.	Increased effectiveness and understanding of delivering investment strategies.
CDOT has implemented additional engagement processes with local planning partners responsible for the National Highway System and broader transportation network.	Improved communication and support to improve asset management practice throughout Colorado.
The Transportation Commission adopted PD 1609.0 in January 2021, as the primary asset management policy directive.	Created clearly defined TAM Program principles, functions, and processes. This included processes for establishing planning budgets and treatment lists.

1.4 TAMP SCOPE AND ORGANIZATION

This plan satisfies all federal requirements for a complete asset management plan, including addressing Colorado's National Highway System (NHS) pavement and bridges, regardless of ownership. The document is organized based on FHWA guidance and includes the following sections.

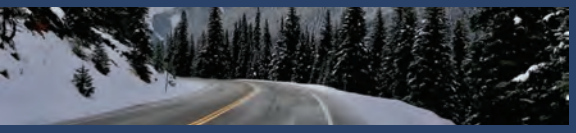
1.4.1 TAMP ORGANIZATION

Introduction: Section 1 (this section) features CDOT's vision for the plan, describes the improvements made to the TAM Program since the previous TAMP period, and establishes the structure of CDOT's 2022 TAMP.

Asset Management at CDOT: Section 2 outlines CDOT's approach to asset management and how it aligns with organizational goals and objectives. This includes asset management's relationship with other planning processes and how the agency plans to continue to advance asset management to help meet statewide infrastructure goals. It also describes the asset-management planning process as it relates to the Statewide Transportation Improvement Program (STIP).

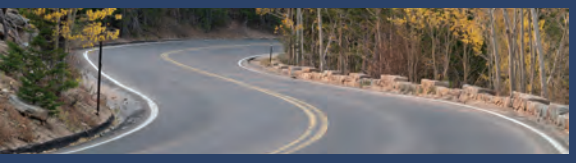
Performance Management: Section 3 presents both federal- and state-established performance measures and CDOT's targets for the entire State Highway System and for NHS pavement and bridges.

Asset Inventory and Condition: Section 4 provides a summary of inventory and condition data for CDOT's pavement and bridge assets. This section also identifies the current condition of these assets, who owns the assets, and which assets are part of the NHS.



Life-Cycle Planning: Section 5 describes how CDOT approaches life-cycle planning. It includes a discussion of how deterioration is modeled and how appropriate treatments are selected. The section also discusses CDOT's management strategies for minimizing life-cycle costs.

Risk and Resilience Management: Section 6 outlines CDOT's approach to risk management within asset management, including processes the Department uses to identify and manage top-priority risks to the overall agency and to asset programs.



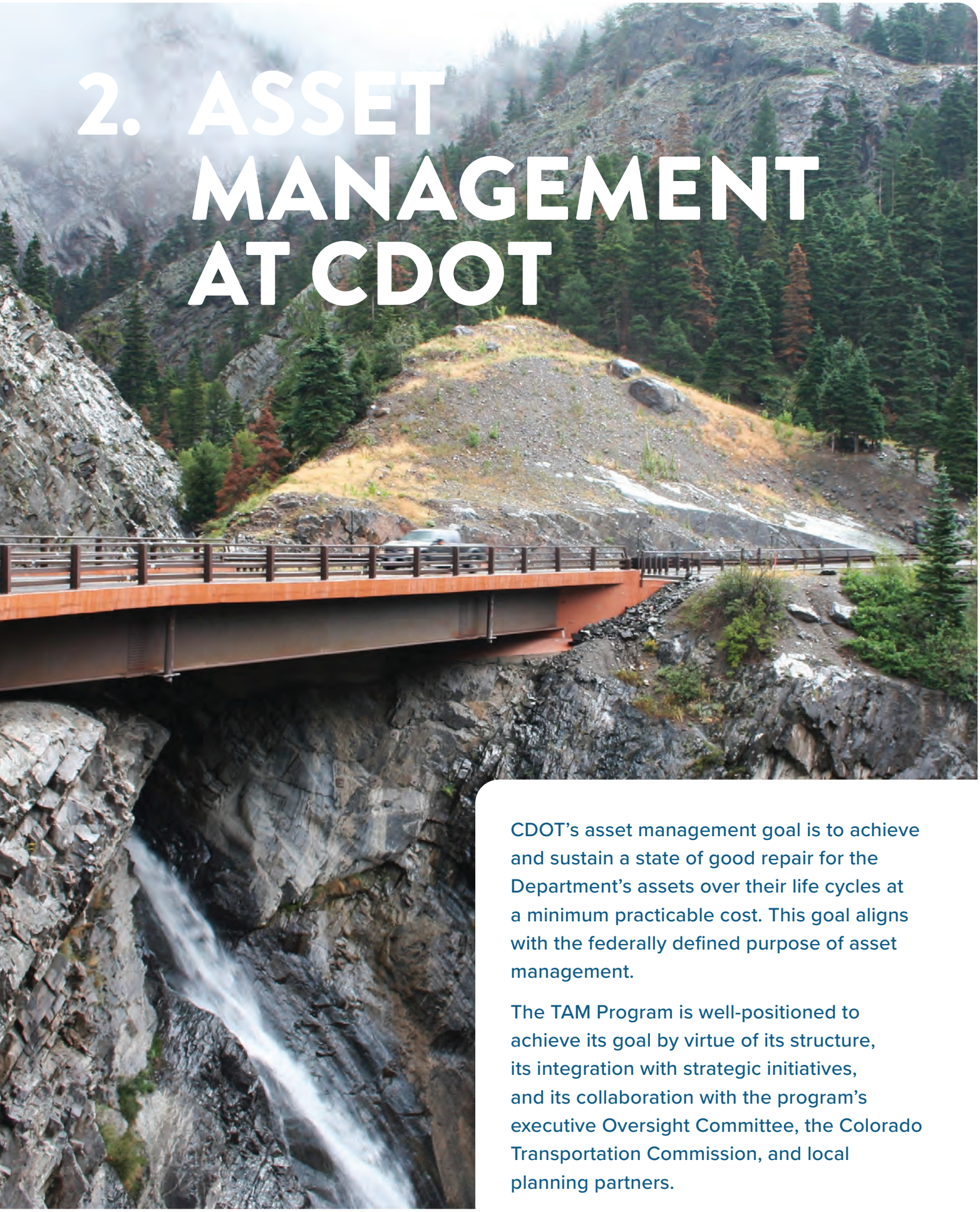
Financial Plan: Section 7 explains CDOT's 10-year financial plan for pavement and bridges, including an overview of revenue streams, sources, and uses; the process for asset-management resource assignment and budget allocation; and asset values. The section also describes the cost to achieve CDOT's "state-of-good-repair" targets.

Investment Strategies: Section 8 identifies investment strategies for CDOT's asset management program. The strategies include estimated spending by work type.

Performance-Gap Analysis: Section 9 describes gaps between current performance and target performance for both federal- and state-established performance measures and CDOT's targets for the entire State Highway System and for the NHS.

Future Improvements: Section 10 identifies process enhancements that CDOT plans to implement. The section discusses near-term opportunities to improve asset management, including ways to strengthen the project selection and prioritization process to advance multiple goal areas.

Appendices: The Asset Plan Appendix consists of asset plans for the 10 other asset classes that—along with pavement and bridges—comprise CDOT's TAM Program: Buildings, Culverts, Fleet, Geohazards, ITS, Maintenance Levels of Service (MLOS), Rest Areas, Traffic Signals, Tunnels, and Walls. Policy Directives 1609.0 and 14.0, and Memo on TAM Treatment Changes are included as Appendix B.



2. ASSET MANAGEMENT AT CDOT

CDOT's asset management goal is to achieve and sustain a state of good repair for the Department's assets over their life cycles at a minimum practicable cost. This goal aligns with the federally defined purpose of asset management.

The TAM Program is well-positioned to achieve its goal by virtue of its structure, its integration with strategic initiatives, and its collaboration with the program's executive Oversight Committee, the Colorado Transportation Commission, and local planning partners.

2.1 TAM PROGRAM PURPOSE

CDOT's mission is to provide the best multimodal transportation system that effectively and safely moves people, goods, and information. The TAM Program develops and implements risk-based strategies to ensure the Department's limited funding is applied to the right project, for the right asset, at the right time.

2.2 PERFORMANCE AND ASSET MANAGEMENT BRANCH

The Performance and Asset Management Branch (PAMB) leads CDOT's asset management, performance measurement, risk and resilience, and economic analysis programs. PAMB empowers CDOT's strategic planning and decision-making by providing tools to measure, analyze, forecast, and communicate the performance of the Department's asset programs and investment decisions to staff and transportation stakeholders. The PAMB's four programs are illustrated in **Figure 3**.

To fulfill these responsibilities, PAMB produces several reports required by statute, as well as voluntary reports and performance-measurement tools. PAMB's asset management efforts include activities that inform project selection and setting planning budgets for asset classes.

2.3 TAM RELATIONSHIP TO OTHER CDOT PLANNING PROCESSES

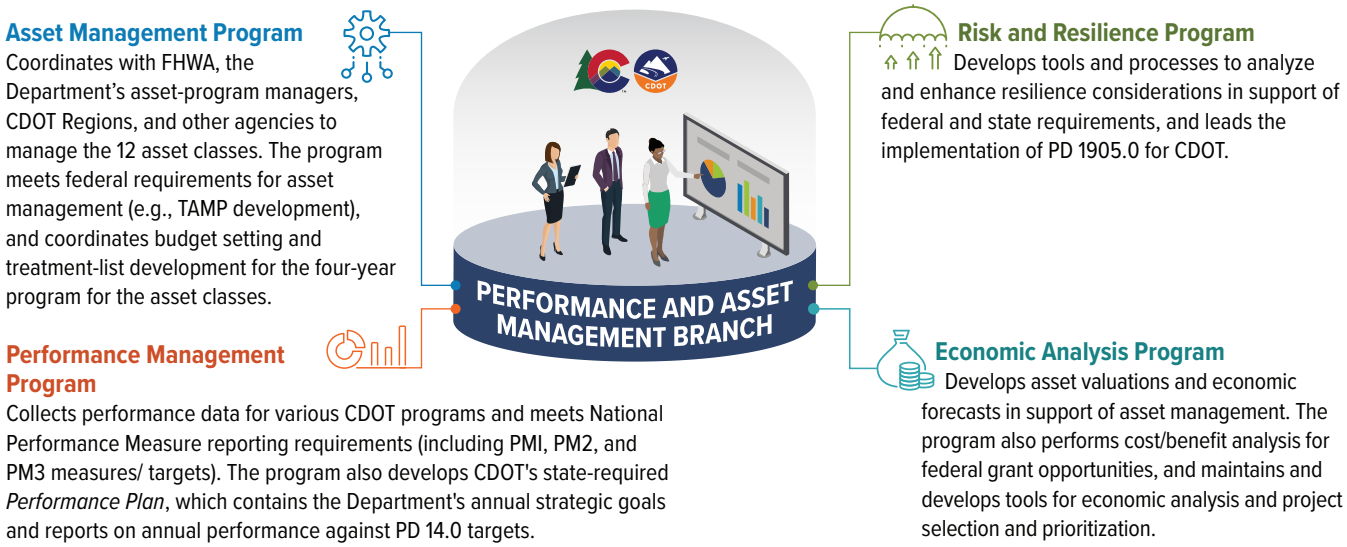
CDOT's *2045 Long Range Statewide Transportation Plan*, published in 2020, aligns with both National Performance Measures and the performance-based approach of PD 14.0, and its focus on the goals of improving asset management, mobility, and safety.

In addition, CDOT understands the importance of linking the TAM Program to broader CDOT planning processes to achieve common goals. Because TAM and Planning both consider long-term network outcomes, better coordination and linkage of life-cycle planning strategies (i.e., asset treatments) and their delivery through projects will increase the efficiency of project delivery and minimize the impact on the traveling public.

In May 2020, CDOT adopted a *10-Year Plan* that identifies transportation strategic investments across the state, ranging from long-deferred resurfacing projects to large and complex projects. The integration of this *10-Year Plan* with the TAM Program is the focus of several initiatives including:

- ***10-Year Plan* Integration in TAM Forecasting.** Wherever possible, projects within the *10-Year Plan* are incorporated within CDOT's Asset Investment Management System (AIMS) model to account for any forecasted condition improvements, and also within the financial plan figures.
- **Tracking Treatments to Projects.** In collaboration with the Program Reporting and Transparency Office, the TAM Program is enhancing processes to track treatments from their initial programming on the four-year TAM treatment lists, through planning, design, procurement, and construction processes.

Figure 3 *PAMB Structure*



Linking systems across CDOT to track these treatments will help compare expected outcomes to actual outcomes.

2.4 TAM ORGANIZATIONAL STRUCTURE

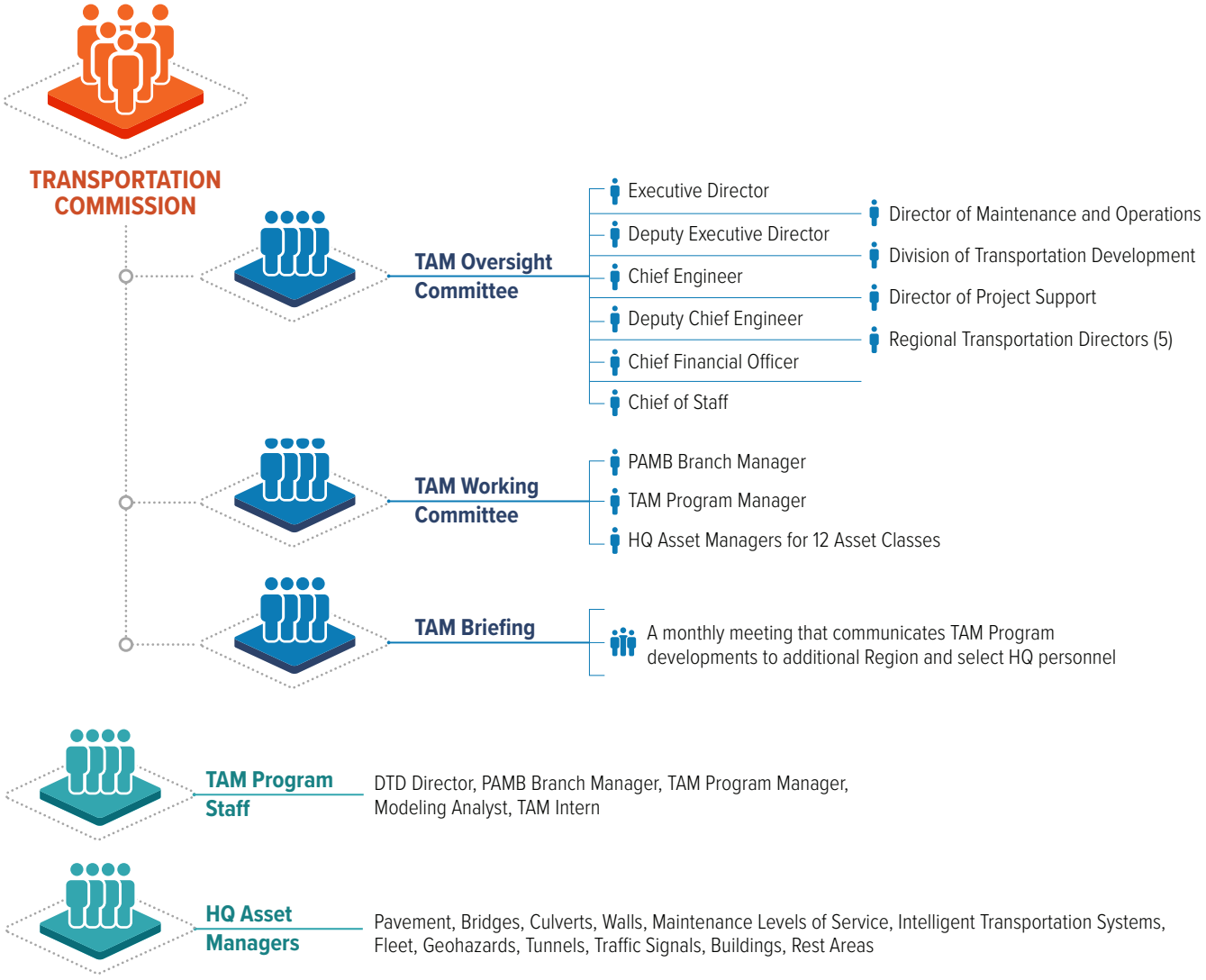
The governance structure of the TAM Program, shown in **Figure 4**, includes the Colorado Transportation Commission, the Transportation Asset Management Oversight Committee (TAMOC) and the Transportation Asset Management Working Committee (TAM Working Committee).

The Transportation Commission sets the program's strategic direction by establishing policies and PD 14.0 performance metrics and targets and by approving annual planning budgets for all asset programs. The TAMOC consists of the Executive Director, Deputy Director, Chief of Staff, Chief Engineer, Deputy Chief Engineer, Chief Financial Officer, Director of Transportation Development, Director of Maintenance and Operations, Director of Project Support, and the five Regional Transportation Directors.

The TAMOC meets monthly and performs a variety of functions, including:

- Establishing federal NPM targets.
- Deciding the yearly TAM Cap, which is the total funding dedicated to the TAM Program each year. The cap is subsequently adopted (or modified) by the Transportation Commission.
- Determining the funding distribution of the TAM Cap among the 12 asset classes. This distribution is subsequently adopted (or modified) by the Transportation Commission.
- Designing the timeline and procedures for the TAM budget-setting process.
- Deciding the process of approving and changing the TAM treatment lists.
- Approving and providing oversight on program documents, such as this TAMP.

Figure 4 *CDOT Asset Management Organizational Structure*



» Providing initial approval for performance metrics and targets for each asset program. Most of these metrics and targets are subsequently adopted or modified by the Transportation Commission as part of PD 14.0.

The TAM Working Committee is a staff-level group that refines asset management processes, develops new four-year treatment lists, maintains and operates asset-modeling systems, and implements other ideas that the TAMOC may introduce. This group includes asset managers for all 12 asset classes and a representative from the Office of Financial Management and Budget (OFMB). The TAM Working Committee works to liaise with the TAMOC and other groups within CDOT, both to obtain feedback on and build buy-in for TAM improvements, impacts, and benefits.

Once a month, Region, finance, and other staff who are less directly involved with the TAM Program attend a briefing on program events, projects, changes, and other updates. This session is another opportunity for TAM Working Committee members to inform and receive feedback.

2.4.1 PLANNING PARTNERS COORDINATION

CDOT and regional FHWA representatives communicate regularly with Colorado's Metropolitan Planning Organizations (MPOs) about performance measures and targets, data collection, and asset management practices. This coordination happens through:

» **Statewide MPO Meetings at CDOT's Headquarters, held monthly.** These meetings allow for collaboration between CDOT and MPO staff on issues related to the state transportation program. Including regular updates on the performance of the system (as measured through federal FAST Act performance measures), sharing of performance data, and collaboration on setting targets for federal performance measures.

» **Colorado Transportation Asset Management User Group (COTAMUG)**. This new group includes cities, counties, MPOs, CDOT, and others. The group discusses general asset management practices, including policy, software, and new ideas.

Coordination with planning partners includes the following data and information processes:

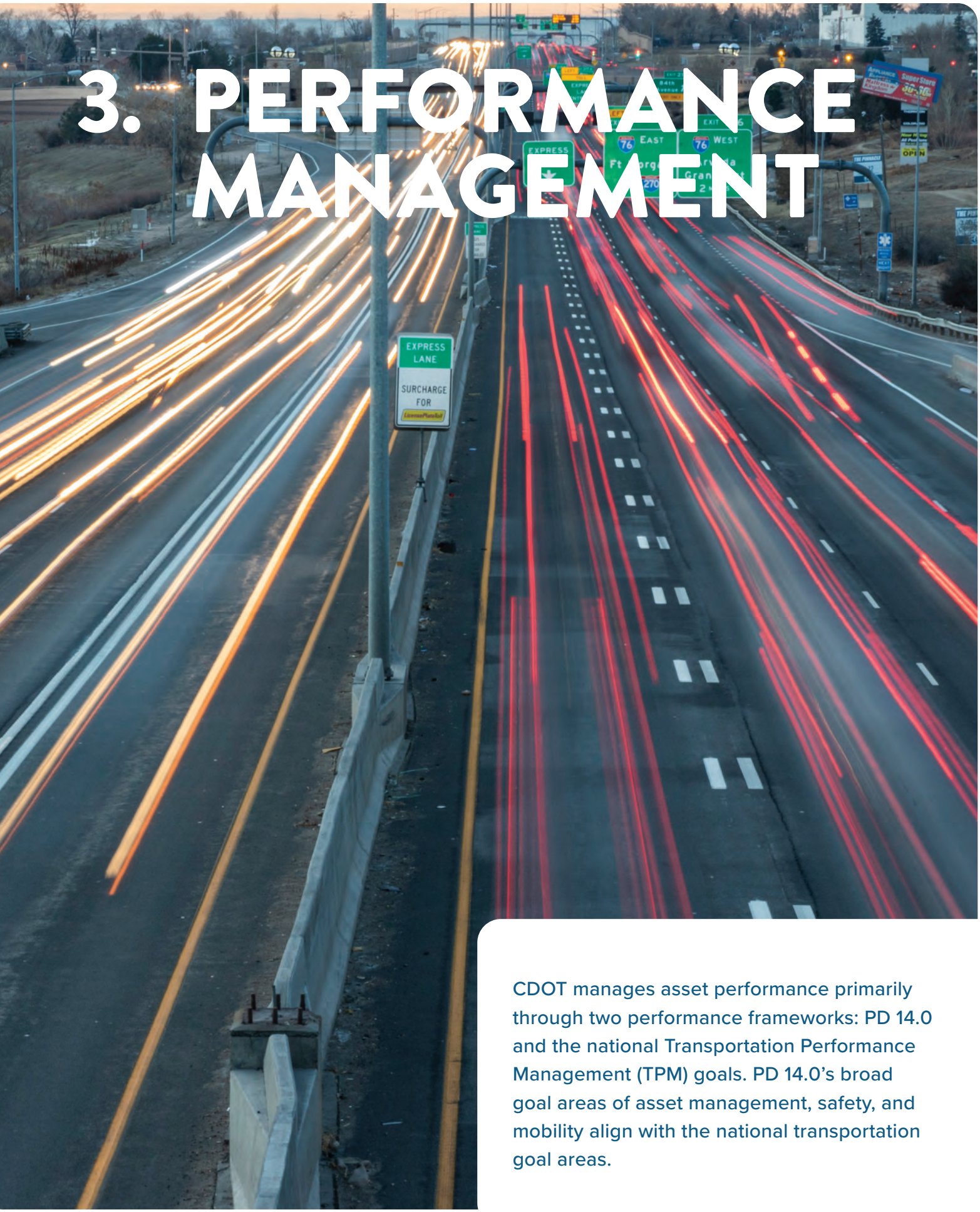
» **Inventory and Condition Data**. CDOT works with MPOs to develop a coordinated data-sharing process and to ensure agreement on responsibilities. The Department collects pavement and bridge condition data for the full NHS, including assets owned by local agencies.

» **Performance Measurement and Target Setting.** CDOT provides historical data on FHWA-required asset-management metrics to help MPOs understand performance trends, especially for bridges and pavement. CDOT has Memorandums of Understanding with each of Colorado's five MPOs that outline the responsibilities of the state and MPOs related to National Performance Measures.

» **Facilities Repeatedly Requiring Repair and Reconstruction Due to Emergency Events (23 CFR 667)**. CDOT is working with local authorities to understand the data that is available to assess repeat damage on all public roads.

CDOT is currently participating in a joint process review with the FHWA Colorado Division to develop approaches to manage the performance of pavement and bridges on the NHS owned by other agencies. The aim of this effort is to establish a formal policy for the management of these NHS assets, such as what, if any, role the Department should have in managing performance.

3. PERFORMANCE MANAGEMENT



CDOT manages asset performance primarily through two performance frameworks: PD 14.0 and the national Transportation Performance Management (TPM) goals. PD 14.0's broad goal areas of asset management, safety, and mobility align with the national transportation goal areas.

3.1 FEDERAL TRANSPORTATION PERFORMANCE MANAGEMENT

The federal Moving Ahead for Progress in the 21st Century Act (MAP-21) and the Fixing America's Surface Transportation (FAST) Act established TPM as a strategic approach that uses information to make investment and policy decisions to achieve national performance goals. As a result, federal National Performance Measures (NPMs) are expected to be integrated into the planning process and project prioritization at state departments of transportation (DOTs). DOTs are expected to invest in projects that achieve state targets for NPMs and contribute to the national goals.

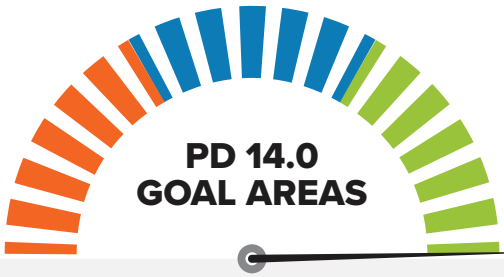
The measures were established by the following laws and regulations:

- 23 USC §150(b) established national goals and performance-management measures that transformed the Federal-aid highway program and provided a means to invest federal transportation funds most efficiently by focusing on performance.
- 23 CFR Part 490 outlined the specific measures required for each state DOT to establish targets and report on a regular basis. Performance is monitored by the FHWA and the Federal Transit Administration (FTA) on a periodic basis, to determine whether the state DOT has made significant progress toward achieving its targets.

CDOT has incorporated the NPMs into its own performance framework, established in the current *Statewide Transportation Plan* and in PD 14.0. This incorporation demonstrates that CDOT's priorities are intertwined with national performance priorities. Performance on the federal metrics is monitored through PD 14.0 "scorecards" and reporting to FHWA.

3.2 PERFORMANCE MANAGEMENT AT CDOT

The Transportation Commission adopted the updated PD 14.0 in 2020, thereby updating CDOT's top performance goals. The revised goals measure success of the Department's efforts to improve in safety, asset management, and mobility, and to guide implementation of the multimodal *Statewide Transportation Plan*. The revised goals also support National Performance Measure goals for surface transportation. Additionally, the updated Policy



Safety

The future of Colorado is zero deaths and serious injuries so all people using any transportation mode arrive at their destination safely.

Asset Management

Maintain a high-quality transportation network by working to maintain a state of good repair for all assets and a highly traversable road network.

Mobility

Reduce travel time lost to congestion and improve connectivity across all modes with a focus on environmental impact, operations, and transportation choice statewide.

Directive aligns performance targets with other key guiding policies, such as Colorado's *Greenhouse Gas Pollution Reduction Roadmap* and HB19-1261 ("Climate Action Plan to Reduce Pollution").

PD 14.0 establishes investment priorities for the Transportation Commission and provides the framework for how CDOT tracks and measures success in achieving those priorities. The following sections in this chapter provide more detail on the different PD 14.0 goals and how performance targets were developed. For asset management and safety, a summary of current performance is also included.

3.3 SAFETY PERFORMANCE

The performance targets for highway safety in PD 14.0 align with targets in the *2020-23 Colorado Strategic Transportation Safety Plan (STSP)*. The development of the STSP is a collaborative, data-driven process that identifies achievable highway-safety targets for 2021-24. PD 14.0 targets apply to all roads in the state. (Targets related to CDOT employee safety are addressed in another document.)

To establish 2022 performance targets for safety, CDOT analyzed fatal-crash data going back to 2002, developed multiple models, created best-fit curves, and determined targets based on examination of the various predicted values. The fatality-rate target assumes that fatal crashes and vehicle miles traveled (VMT) are both increasing in the near term.

Contributing factors were considered, including population growth, increases in VMT, economic growth, potential funding changes, and legislative changes. All models indicated future increases in fatality rates. As a result, CDOT's short-term safety performance targets recognize an uptick in the fatality rate, and the need to continue focusing on programs that reduce crashes to achieve goals. The long-term vision for the state, captured in the *State Transportation Safety Plan*, is the aspirational goal of moving Colorado toward zero deaths.

Although forecast models using regression and exponential smoothing models were applied to predict 2022 numbers, the increase in fatalities and decrease in travel volume in the pandemic year of 2020 were deemed too uncertain to accurately project the number of fatalities and serious injuries in subsequent years. As a result, CDOT executive leadership directed that calendar 2019 numbers be used as the target for the 2018-22 five-year average.

Figure 5 presents the 2022 highway safety performance targets per PD 14.0 and National Performance Measures.

Figure 5 *2022 Highway Safety Performance Targets Per PD 14.0 and Federal Requirements*

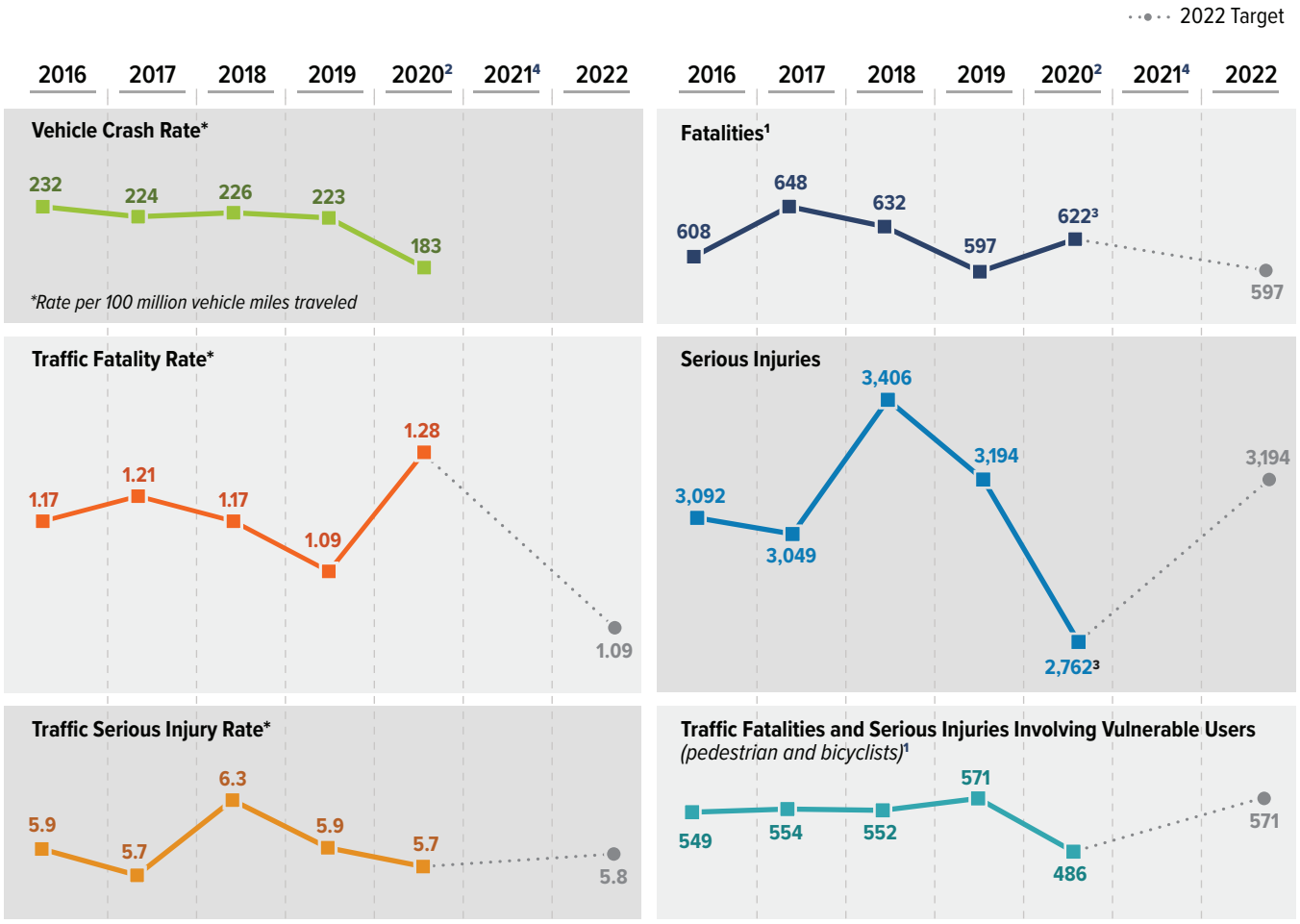


Figure 5 Notes:

[1] Measures aligned with FHWA Safety Performance Management measures. The number of fatalities and number of serious injuries are not listed in PD 14.0 but are tracked as part of federal reporting requirements and as an input to rate measurements.

[2] Annual performance figures shown here. Federal reporting considers five-year averages. Both numbers are reported here: https://www.fhwa.dot.gov/tpm/reporting/state/safety.cfm?state=Colorado

[3] 2020 (pandemic year) is seen as having fatalities and serious injuries that do not follow recent trends.

[4] 2021 data not yet available.

3.4 ASSET MANAGEMENT PERFORMANCE

CDOT's performance targets for asset management, which are contained in PD 14.0, are intended to be achieved or maintained over 10 years (2021-30) and are aligned with federal requirements. The performance targets are used to help determine funding levels for each of the 12 asset classes within CDOT's asset management program.

The performance targets were developed in part through analysis from the AIMS model. The Department regularly evaluates various investment strategies produced by AIMS to determine which is best to meet performance targets. Based on the AIMS analysis, the Department may alter its existing strategy by adjusting treatments, funding levels, and condition targets to help close performance gaps.

Performance targets per PD 14.0 and the 2021 performance levels for asset classes in the TAM Program are summarized in **Table 1**. Further discussion on these targets, along with current and future performance, is provided in the remainder of this TAMP for pavements and bridges, and within the Asset Plan Appendix for other assets.

Table 1 *Asset Management Performance Targets Per PD 14.0*

Asset Class	Unit	2021 Inventory	PD 14.0 Performance Measure	Target	2021 Performance (unless stated)
Pavement	Lane Miles	23,016	Percent with high or moderate Drivability Life	80%	All 2020: 89% Interstate, 82% NHS, 79% State Highway System
Bridges	Number of State-Owned Bridges	3,464	Percent deck area on NHS and State Highway System in good condition, and percent deck area in poor condition[1]	40% or > in good condition	37.3% NHS, 37.1% State Highway System
				10% or < in poor condition	5.1% NHS, 5.6% State Highway System
Maintenance Levels of Service (MLOS)	N/A	N/A	Level of Service for State Highway System	MLOS B- grade	C-
Buildings	Number of Buildings	1,009	Average Statewide Letter Grade	85% C or better	49% Graded C or Better
ITS	Number of Devices	3,709	Average percent of life expended	90% or below	70%
Fleet	Number of Vehicles	3,219	Average percent of life expended	75% or below	69%
Tunnels	Length in Miles, Number of Tunnels	7 miles (approx.), 20 tunnels	Percent of tunnel length (all elements) in equal or better condition than 2.5 weighted condition index	75% or above	39% (2020)
Culverts	Number of Culverts	5,946	Percent rated poor	5% or below	5.4%
Geohazards	Hazardous Road Segments	3,437	Percent of segments at or above risk grade B	85% or above	75%
Signals	Signals Assemblies	1,852	Percent of signal infrastructure in severe condition	2% or below	7%
Walls	Square Feet	14 million	Percent of CDOT-owned walls, by square foot, in poor condition (have a rating of 4 or less)	2.5% or below	3.5%
Rest Areas	Number of Sites	26	Average Statewide Letter Grade	90% C or better	63% C or Better

PD 14.0 also sets out performance measures and targets for transit assets that align with FTA requirements.

1 See Bridge section for secondary measures.

3.4.1 NATIONAL PERFORMANCE MEASURE TARGETS

The Department's current FHWA National Performance Measure (NPM) targets for the NHS are listed in **Table 2**. Further discussion on the differences between the two pavement measures (Drivability Life and NPM) is included in Section 4.2.2 (Page 17).

Table 2 *NHS National Performance Measure Targets*

Asset Class	FHWA National Performance Measure Targets
Interstate Pavement	2-Year target (2023) 45% Good, 4% Poor 4-Year target (2025) 47% Good, 3.5% Poor
Non-Interstate NHS Pavement	2-Year target (2023) 42% Good, 3.5% Poor 4-Year target (2025) 43% Good, 3.5% Poor
Bridge	2-Year target (2023) 36% Good, 4% poor 4-Year target (2025) 36% Good, 4% Poor

3.5 MOBILITY PERFORMANCE

PD 14.0 requires CDOT to coordinate and collaborate with internal and external partners to achieve mobility goals in Colorado. Through this collaborative approach, CDOT will take actions to fulfill the goals outlined within the Department's Greenhouse Gas Pollution Reduction Roadmap.

PD 14.0 performance targets within the mobility goal area are intended to be achieved during the 2021-30 timeframe. A portion of the targets within the goal area are aligned with the CDOT *Greenhouse Gas Pollution Reduction Roadmap*, and HB19-126—Climate Action Plan to Reduce Pollution. Other targets within the goal area help increase reliability of the State Highway System and increase the use of multimodal travel statewide. The mobility performance measures cover a wide range of items and are not included here in detail. The areas of focus covered by mobility include:

- Reliability and congestion
- Environmental impact
- Multimodal options

CDOT provides an annual update to the Transportation Commission on PD 14.0 measures.

3.5.1 NATIONAL PERFORMANCE MEASURE TARGETS

In addition to PD 14.0 mobility targets, CDOT defines National Performance Measure targets for System Reliability and Congestion Mitigation and Air Quality (CMAQ). These targets were established by using forecasts from the National Performance Management Research Data Set (NPMRDS), supplemented with Highway Performance Monitoring System (HPMS) data, CDOT Online Transportation Information System (OTIS) traffic volumes, and short-term vehicle class counts.

To establish Congestion Mitigation and Air Quality (CMAQ) targets, CDOT reviewed the emission-reduction benefit from previous years to establish the targets for each emission-reduction benefit that must be reported.

3.6 COORDINATION, REPORTING, AND IMPLEMENTATION

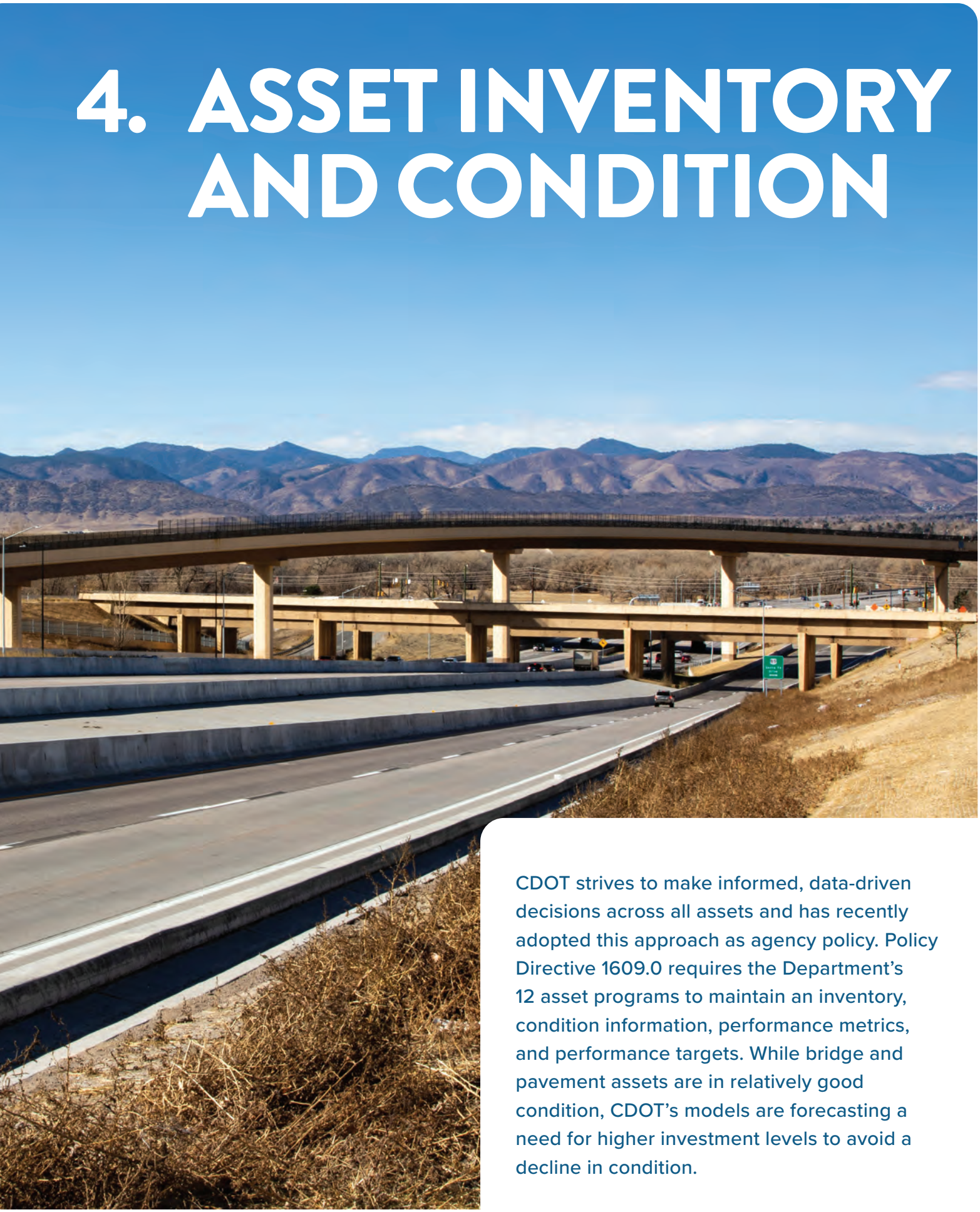
CDOT works closely with MPOs to establish, report, and implement Colorado's performance targets for National Performance Measures. A summary of the coordination process for target setting for each goal area is as follows:

- **Safety**—Four of the five MPOs in the state chose to support the state targets for the past four target-setting periods (i.e., 2019, 2020, 2021, 2022). The Denver Regional Council of Governments (DRCOG) chose to establish its own targets for each of the safety performance measures within its MPO boundary for each year.
- **Asset Management**—All MPOs in Colorado chose to support the state targets for pavement and bridge condition, including the original targets in 2018 and target revisions in 2020.
- **Mobility**—All MPOs in Colorado chose to support the state targets for the system reliability and congestion metrics. Only three of the five MPOs are in nonattainment or maintenance with regards to national ambient air quality standards pollutants in the state. DRCOG and North Front Range MPO were federally required to establish specific targets for projects administered and to establish targets (in conjunction with CDOT) for traffic congestion measures.

Section 2.4.1 discussed MPO coordination for delivering asset management outcomes for the NHS and the broader transportation network.

23 CFR 490 requires state DOTs and MPOs to establish performance targets for the National Performance Measures.

4. ASSET INVENTORY AND CONDITION

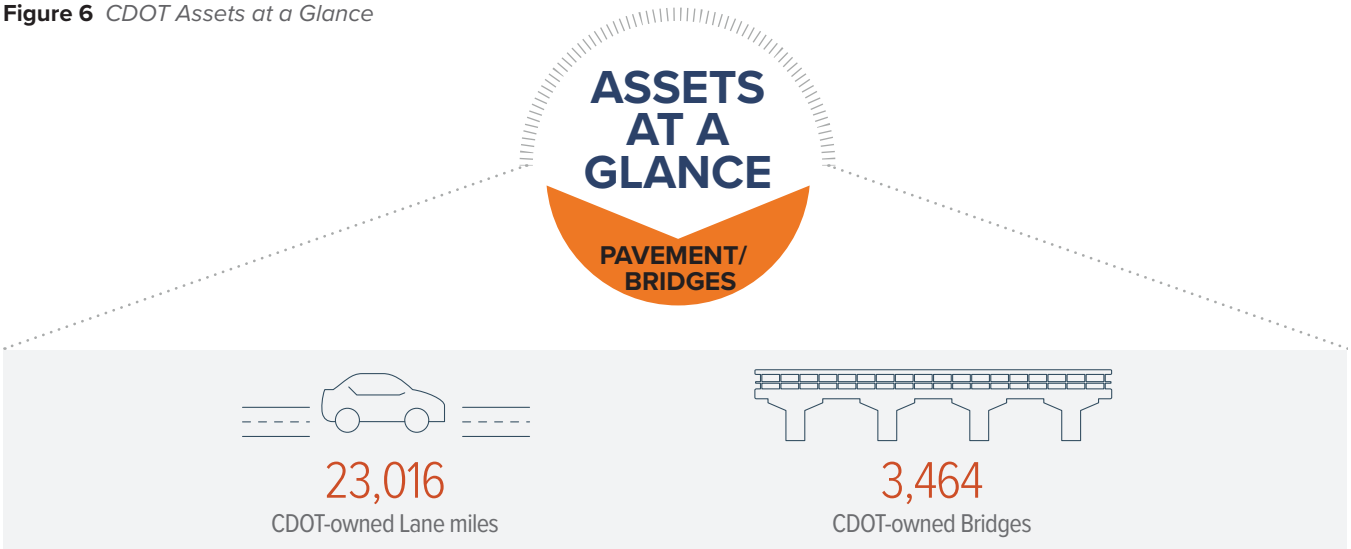


CDOT strives to make informed, data-driven decisions across all assets and has recently adopted this approach as agency policy. Policy Directive 1609.0 requires the Department's 12 asset programs to maintain an inventory, condition information, performance metrics, and performance targets. While bridge and pavement assets are in relatively good condition, CDOT's models are forecasting a need for higher investment levels to avoid a decline in condition.

4.1 ASSETS AT A GLANCE

Pavement and bridge assets reach every corner of the state—crossing the continental divide, spanning lakes and rivers, and connecting Coloradans to seven neighboring states. Pavements and bridges form the backbone of the highway system and are the system's highest-valued assets in terms of replacement cost. **Figure 6** summarizes CDOT's inventory of pavement and bridge assets.

Figure 6 *CDOT Assets at a Glance*



This chapter provides details on the process, performance measures, targets, and current inventory and condition data for pavements and bridges. Details for other assets are included within the Asset Plan Appendix.

4.2 PAVEMENT

Since 1991, CDOT has collected pavement condition data annually—between January and June—to understand the physical conditions of the roadway network. The Department uses an outside vendor to collect high-speed, automated pavement-condition data for the full CDOT pavement network, including the full National Highway System (NHS) and Highway Performance Management System (HPMS) sample segments. In collaboration with CDOT staff, the vendor collects data and performs quality management consistent with federal requirements. Historically, CDOT collected data for its internal performance measures: Remaining Service Life (RSL), and as of 2013, Drivability Life (DL). As federal requirements have changed over time, CDOT has expanded the data it collects. Currently, the primary data collected aligns with the pavement condition metrics in FHWA regulations. This includes International Roughness Index data, cracking percent, rutting, and faulting (23 CFR 490.311), and others including surface type and section location (23 CFR 490.309(c)). CDOT uses this historical condition data to develop deterioration models and predict future conditions.

CDOT has developed standard protocols and quality-management procedures to meet the reporting requirements for both the federal National Performance Measure and the CDOT Drivability Life metric. The quality-management process involves activities such as the specification of data-collection protocols, quality criteria, personnel responsibilities, quality control, quality acceptance, corrective action, and quality-management documentation. The standard protocols followed by CDOT for the four pavement-condition metrics required by FHWA regulations (23 CFR 490.311) are documented in the Department's Pavement Data Quality Management Plan (QMP).

4.2.1 INVENTORY

CDOT owns and maintains 23,016 lane miles of highways as of 2020. Lane miles are calculated by measuring the centerline length of a road and multiplying that number by the total number of lanes on the road. CDOT's highways include 15,491 lane miles of pavement on the NHS and 9,500 lane miles of pavement not on the NHS. FHWA only requires NHS pavement to be included in the TAMP. CDOT-owned NHS comprises 4,164 lane miles of Interstate system and 9,352 lane miles of non-Interstate NHS. Local agencies own and maintain an additional 1,975 lane miles of the non-Interstate NHS. CDOT

exclusively owns and maintains the Interstate pavement, while CDOT coordinates with other municipalities and counties to operate the non-Interstate NHS pavement. Thus, CDOT owns 87 percent of pavement on the NHS (13,516 lane miles) in Colorado, while local agencies own the remaining 13 percent. **Figure 7** summarizes CDOT's owned lane miles and NHS lane miles, both CDOT and locally owned.

Table 3 below presents a breakdown of locally owned NHS pavement inventory and condition within each Colorado MPO jurisdiction.

4.2.2 PERFORMANCE MEASURES

In this TAMP, CDOT assesses NHS pavement condition using two approaches. The first approach uses an internal performance metric, Drivability Life. The second approach uses National Performance Measures that evaluate NHS pavement in terms of the percentage of lane miles classified as being in Good or Poor condition.

CDOT Drivability Life

The first approach to reporting pavement performance is CDOT's internal measure of Drivability Life. CDOT has assessed pavement network conditions using Drivability Life since 2013. Drivability Life combines similar distresses used for computing the FHWA National Performance Measures and incorporates additional distresses (e.g., corner breaks for concrete pavements only, as well as additional asphalt pavement distresses such as longitudinal

DRIVABILITY LIFE CATEGORIES

CDOT Internal Measures used to assess CDOT Pavement Network Condition:

- **HIGH: DL ≥ 11 YEARS**
- **MODERATE: DL = 4—10 YEARS**
- **LOW: DL ≤ 3 years**

Figure 7 *Colorado Highway Network Breakdown (lane miles)*

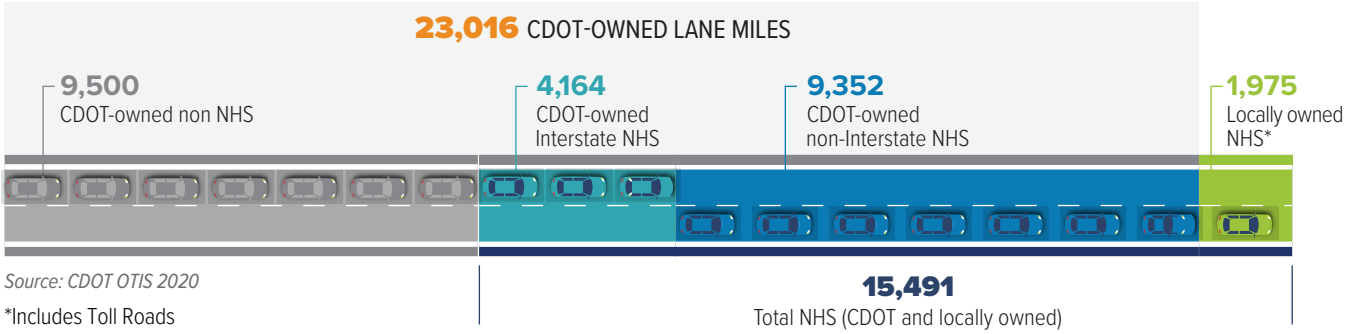


Table 3 *Inventory of Locally Owned NHS Pavement and 2020 Condition*

Agency	Good	Fair	Poor
Denver Regional Council of Governments—Centerline Miles	32.3	242.5	37.7
Lane miles	126.1	986.1	141.2
Percent of lane miles	10.0%	78.7%	11.3%
Pikes Peak Area—Centerline Miles	45.6	120.9	10.5
Lane miles	171.3	480.5	35.8
Percent of lane miles	24.9%	69.9%	5.2%
Pueblo Area—Centerline Miles	0.9	0.7	0.4
Lane miles	1.8	1.3	0.8
Percent of lane miles	45.9%	33.7%	20.4%
Grand Valley—Centerline Miles	0	1	0
Lane miles	0	2.8	0
Percent of lane miles	0%	100%	0%

and transverse cracking). However, Drivability Life communicates different information and uses different distress thresholds than the National Performance Measures. Drivability Life is an indication in years of how long a highway segment will have acceptable driving conditions based on an assessment of pavement distresses that measure smoothness and safety. Drivability Life implements traffic-based highway categories, associated category drivability condition standards, and allowable pavement treatments. Unacceptable driving conditions are specific to each traffic-based highway category and means drivers must reduce speeds to compensate for poor conditions, navigate around damaged pavement, or endure intolerably rough rides. There are three categories of Drivability Life: High (greater than 10 years of Drivability Life remaining); Moderate (four to 10 years remaining); and Low (three or fewer years remaining).

National Performance Measure (NPM)

The second method for reporting pavement performance uses the National Performance Measure for pavement, which is how FHWA monitors states' progress toward meeting federally required performance targets for the NHS. CDOT calculates the federal measure using the following distresses: International Roughness Index (IRI), rutting (asphalt pavements only), faulting (concrete pavements only), and cracking percentage. To calculate the performance of a particular pavement section, CDOT combines the four distresses in accordance with FHWA-established condition thresholds. **Figure 8** shows the thresholds.[2]

NATIONAL PERFORMANCE MEASURES FOR PAVEMENT

Used to assess National Highway System pavement:

- % INTERSTATE IN GOOD CONDITION
- % INTERSTATE IN POOR CONDITION
- % NON-INTERSTATE NHS IN GOOD CONDITION
- % NON-INTERSTATE NHS IN POOR CONDITION

CDOT establishes National Performance Measures targets by:

- Taking an inventory of pavement and bridge conditions on the Interstate and non-Interstate NHS, based on federal standards.
- Analyzing these condition data and other inputs (e.g., deterioration, treatment costs, life-cycle investment strategies, etc.) to forecast future conditions through asset models.
- Considering factors outside the models, or prioritizing certain factors more than the model (e.g., project lists, recent historical trends, etc.).
- Proposing targets to the Transportation Asset Management Oversight Committee for approval.

Figure 8 *Federal Pavement Metric Thresholds*

	Good	Fair	Poor
IRI (inches / mile)	<95	95-170	>170
Cracking Percent (%)	<5	CRCP*: 5-10 Jointed Concrete: 5-15 Asphalt: 5-20	>10 >15 >20
Rutting (inches)	<0.20	0.20 - 0.40	>0.40
Faulting (inches)	<0.10	0.10 - 0.15	>0.15

* CRCP = Continuously Reinforced Concrete Pavement

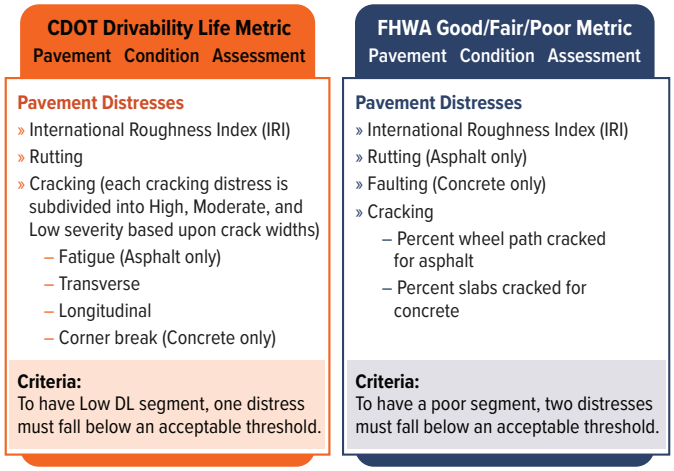
2 US 49 CFR 1.85 Part 490 – National Performance Management Measures

Use of CDOT Drivability Life and FHWA's National Performance Measures

Figure 9 shows the different distresses and criteria used in computing National Performance Measures and Drivability Life. The key distinction between the two metrics is that for a pavement segment to be classified as Low Drivability Life, *only one* of the distresses (IRI, rutting, transverse cracking, longitudinal cracking, fatigue cracking, or corner breaks) needs to be rated as Low. In contrast, under the National Performance Measures, a segment is classified as Poor if *two or more* distresses (IRI, cracking percent, and rutting or faulting) are Poor. This difference leads to fewer segments classified as Poor when using the national measures than are classified as Low under Drivability Life.

CDOT continues to use Drivability Life as the primary driver for pavement management and resource allocation, while using the National Performance Measures to meet federal reporting requirements.

Figure 9 *Comparison of Drivability Life and National Performance Measures*



4.2.3 TARGET SETTING

Table 4 shows PD 14.0 condition targets for pavement versus 2020 performance. CDOT achieved most targets for each measure. The table indicates how targets for Drivability Life are specific to the type of roadway, based on functional classification. Green indicates the target was achieved; red indicates the opposite.

2020 data has been used for pavements within this TAMP.

4.2.4 CONDITION

Under National Performance Measures, 46.3 percent of the Interstate NHS pavement was in Good condition in 2020, while 49.8 percent was in Fair condition, and 3.9 percent was in Poor condition. Additionally, 41.7 percent of non-Interstate NHS pavement was in Good condition, 55.0 percent was in Fair condition, and 3.3 percent was Poor. Under the FAST Act, there is a minimum performance level for Interstate pavement condition in Poor condition. If a state exceeds 5 percent Poor, they lose flexibility of a portion of federal funds. Specifically, they must obligate a set amount of funds to eligible projects on pavements on the Interstate until the condition exceeds the minimum standard. To date, CDOT has avoided this restriction.

Using CDOT's Drivability Life metric, about 89 percent of the Interstate NHS had High or Moderate Drivability Life, and 11 percent had Low Drivability Life. At 89 percent High or Moderate Drivability Life, CDOT's Interstate pavement condition is nine percentage points more than the state's PD 14.0 target of 80 percent. This indicates that CDOT is making significant efforts to make the best use of resources to maintain the system in a state of good repair. In addition, about 29 percent of non-Interstate NHS pavement had High Drivability Life, 53 percent had Moderate Drivability Life, and 18 percent had Low Drivability Life. Thus, CDOT achieved the PD 14.0 targets for the NHS while also being close to meeting the State Highway targets.

Table 4 *CDOT PD 14.0 Measures for Pavement—Drivability Life*

Asset	Measure	2020 Performance	Target
Pavement **Percentage high/moderate Drivability Life**	Interstate	89%	80% or greater
	CDOT-owned NHS (excluding Interstates)	82%	80% or greater
	State Highway System (including Interstate and CDOT-owned NHS)	79%	80% or greater

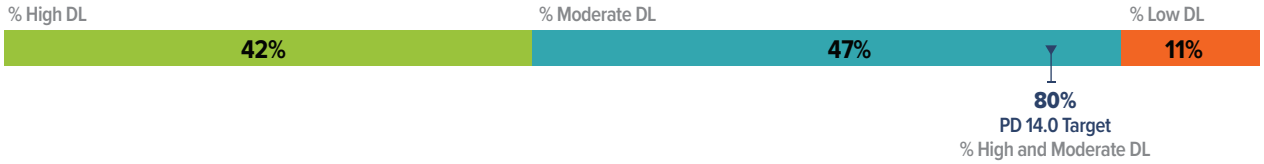
Figure 10 summarizes the current FHWA and CDOT pavement condition ratings along with the number of lane miles in each classification for each condition category.

Figure 10 *CDOT Pavement Current Condition Snapshot*

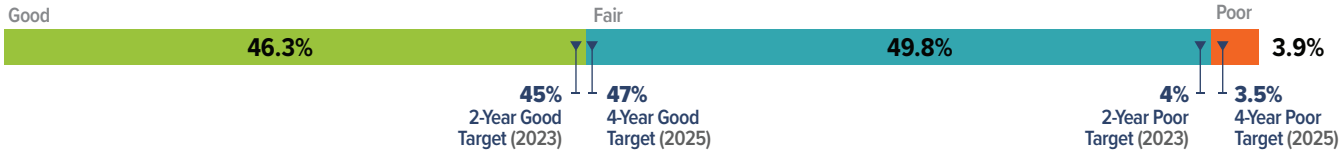
Interstate and Non-Interstate NHS performance targets are currently being met for Drivability Life. For the overall State Highway System, condition is one percentage point behind the DL target. CDOT is on track to meet National Performance Measure targets.

INTERSTATE NHS

Drivability Life
2020 Condition

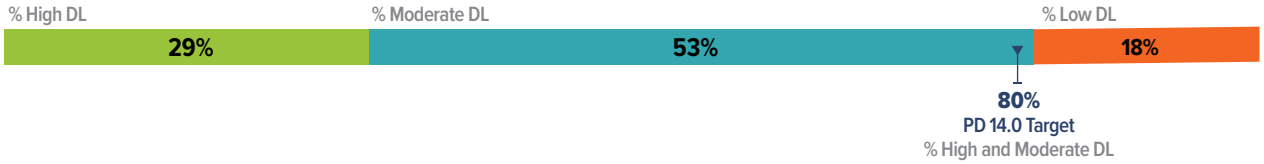


National Performance Measures
2020 Condition

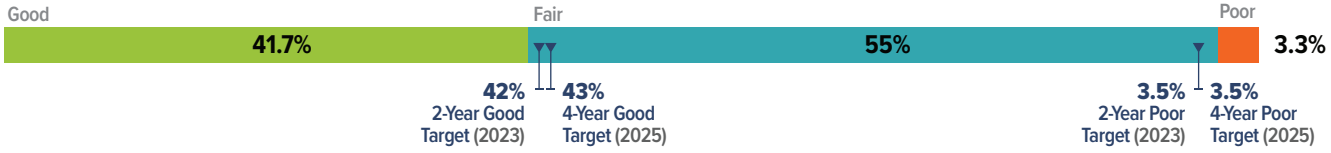


NON-INTERSTATE NHS

Drivability Life
2020 Condition

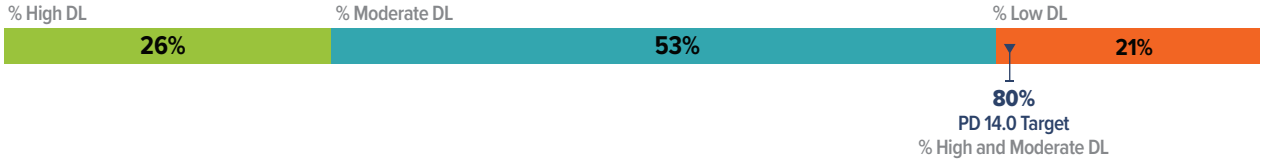


National Performance Measures
2020 Condition



CDOT STATE HIGHWAY SYSTEM

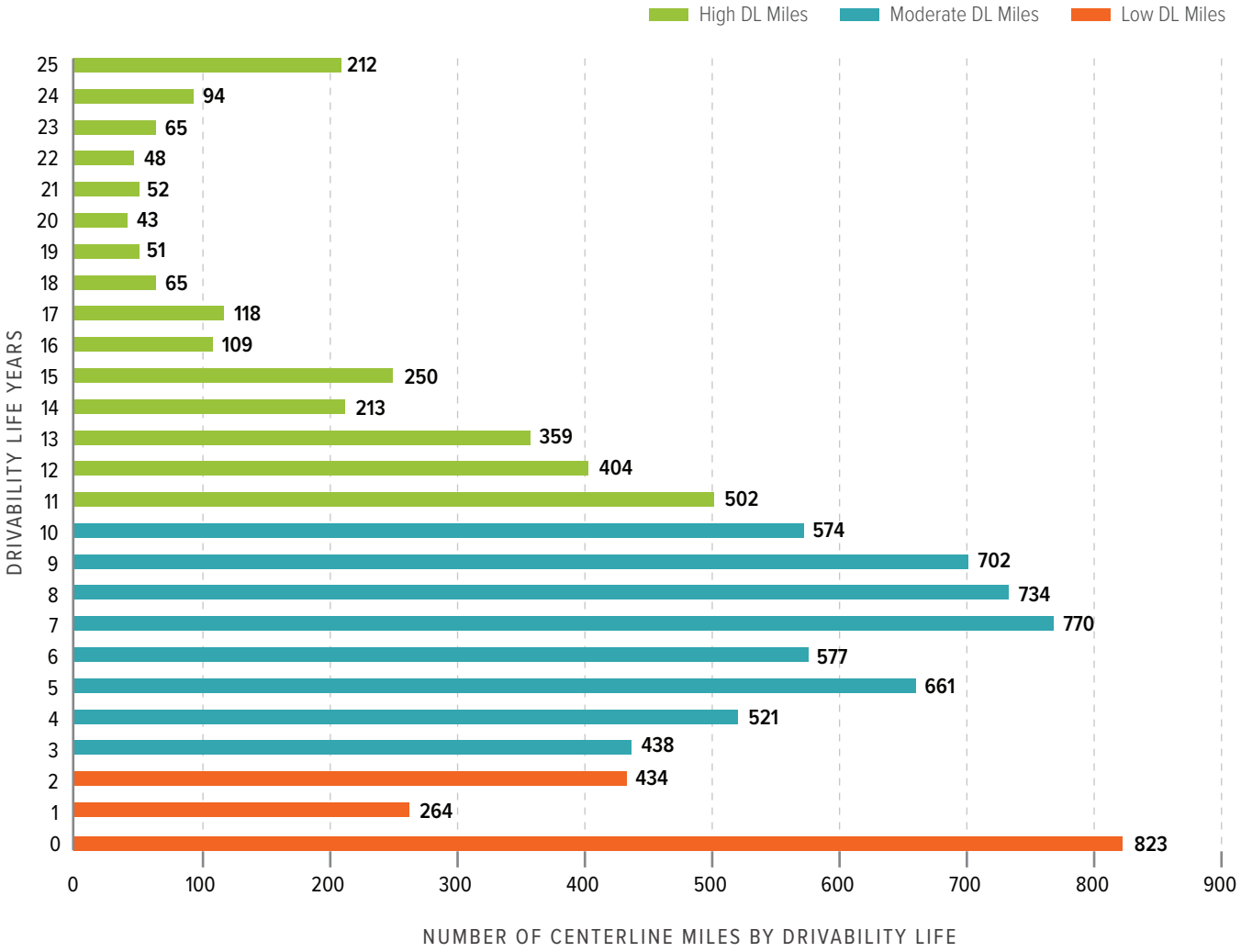
Drivability Life
2020 Condition



Although CDOT is meeting many of its pavement targets, challenges remain. **Figure 11** illustrates that about 50 percent of the network currently has Moderate Drivability Life. About 30 percent of the network rated moderate is forecasted to deteriorate to Low Drivability Life within four years.

Figure 11 *CDOT Current Pavement Condition Drivability Life Profile*

50% of lane miles are in moderate condition. Many of these (30% over the next 4 years) are expected to fall into low condition.



4.2.5 CONDITION TRENDS

Figure 12 shows the historic performance trend of the different classes of pavements according to Drivability Life. Generally, state highway pavement conditions have improved over time.

Such condition trends provide insight into future performance. CDOT uses these trends, projected funding, expert knowledge, and decision-support tools to establish performance targets. In 2022, the Department has updated its 2024 (two-year) and 2026 (four-year) performance targets for the National Performance Measures. Drivability Life metrics have also been reassessed as part of this process (Drivability Life metrics were originally established in 2013). See Section 3 for more information on setting targets and how they relate to investment decisions.

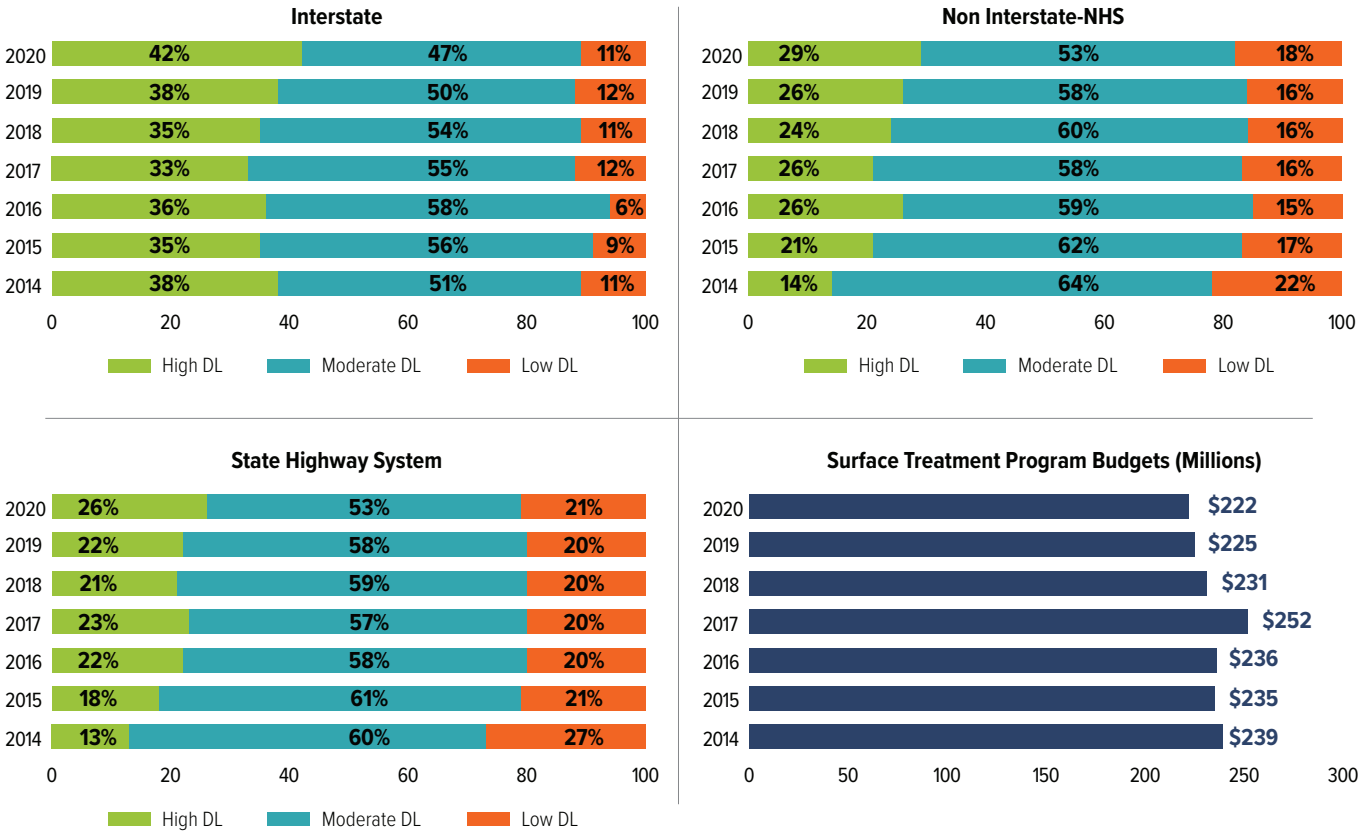
4.3 BRIDGES

Bridges are referred to within CDOT as Major Structures, which are defined as vehicular bridges or culverts with a clear opening of greater than 20 feet along the direction of the roadway[3].

CDOT inspects the condition of major bridges and major culverts according to National Bridge Inspection Standards (NBIS). The NBIS provides standards for inspecting and rating the nation's bridges based on materials and the physical condition of the deck, superstructure, and substructure of bridges, and the overall condition of culverts. As required by federal regulations, structures subject to the NBIS are inspected at least once every two years, although they may be inspected more frequently if the structure is deemed a risk by the bridge inspection manager. In addition, the inspection interval may be up to four years with written FHWA approval.

Figure 12 *Condition Trends for Colorado Pavements Using Drivability Life Metric and Historical Investments*

The amount of Good pavements has increased since 2014. For Interstate pavement, the amount of Poor pavements has increased since 2015. For the Non-Interstate NHS and State Highway System, the amount of Poor pavements has remained constant.

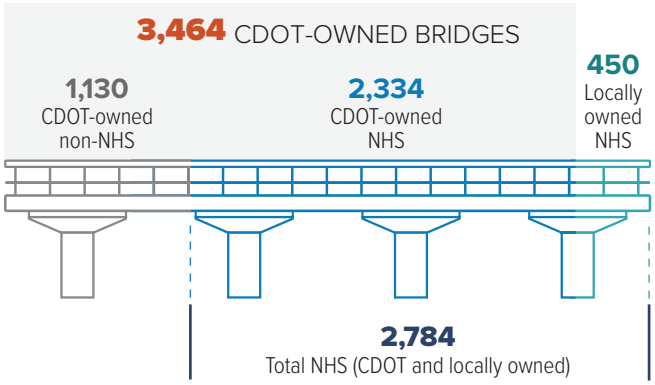


3 An opening may be between abutments, spring lines of arches, extreme ends of openings for multiple boxes, or extreme ends of openings for multiple pipes.

4.3.1 INVENTORY

CDOT owns and maintains 3,464 bridges with about 34.2 million square feet of bridge deck area as of 2021. There are 2,784 bridges on the NHS in Colorado. CDOT owns 2,334, or 84 percent, of the bridges on the NHS, while the other 16 percent of NHS bridges are locally owned, as shown in **Figure 13** and **Table 5**.

Figure 13 *CDOT and NHS Bridges in Colorado*



The Department has two bridge programs:

- **The Colorado Bridge Preservation Program (Staff Bridge)** inspects, maintains, repairs, rehabilitates, and replaces CDOT's major structures.
- **The Statewide Bridge and Tunnel Enterprise (BTE)** finances, repairs, reconstructs, and replaces designated Poor-rated major structures.

The Colorado Bridge Enterprise (CBE) was formed in 2009 as part of the state's Funding Advancement for Surface Transportation and Economic Recovery (FASTER) legislation (SB 09-108). In 2021, the passage of the Sustainability of the Transportation System legislation (SB 21-260) expanded the existing CBE to include surface transportation projects for tunnels and renamed the expanded enterprise as the Statewide Bridge and Tunnel Enterprise (BTE). BTE operates as a public-private enterprise within CDOT, with the Colorado Transportation Commission serving as the BTE Board. The majority of CDOT's bridges are managed by CDOT's bridge unit (Staff Bridge), while the BTE manages structures where ownership has been transferred to the state-run enterprise, as described below.

The business purpose of the BTE is to finance, repair, reconstruct, and replace bridges with a Poor rating and then maintain those bridges. Bridges with a Poor rating are eligible for BTE funding and are transferred to BTE after project completion (for replacement structures) or prior to construction (for rehabilitation projects). While the bridges remain state-owned, direct control and maintenance of the structures becomes the responsibility of the BTE. There are currently 110 BTE assets, of which 68 are on the NHS. BTE has its own prioritization process for selecting which Poor-rated, CDOT-owned bridges it will rehabilitate or replace.

4.3.2 PERFORMANCE MEASURES

Based on federal guidelines, CDOT assigns structures an overall condition of Good, Fair, or Poor according to the following criteria:

- For bridges: the minimum NBIS condition rating of the deck, superstructure, or substructure.
- For culverts: the NBIS condition rating.

If the NBIS rating is four or below for any of the three bridge components or for the culverts rating, the structure is classified as Poor (See **Figures 14 and 15**). Bridges in Poor condition are classified as Structurally Deficient, but this does not mean the bridge is unsafe. It is important to note that the conditions of Poor and Structurally Deficient are now synonymous, despite historically having different definitions.

Table 5 *CDOT and NHS Bridge Ownership*

Asset	Number	Deck Area *(square feet)*
CDOT-owned Bridges	3,464	34.2 million
NHS Bridges (owned by CDOT, and local agencies)	2,784	32.4 million
CDOT-Owned NHS Bridges	2,334	26.9 million
CDOT "Staff Bridge" Unit	2,266	25.7 million
Statewide Bridge and Tunnel Enterprise (BTE)	68	1.2 million
Local Agency NHS Bridges	450	5.5 million

Source: National Bridge Inventory for CDOT, 2021

Figure 14 *CDOT Major Structures, Including NBIS Bridge Components*

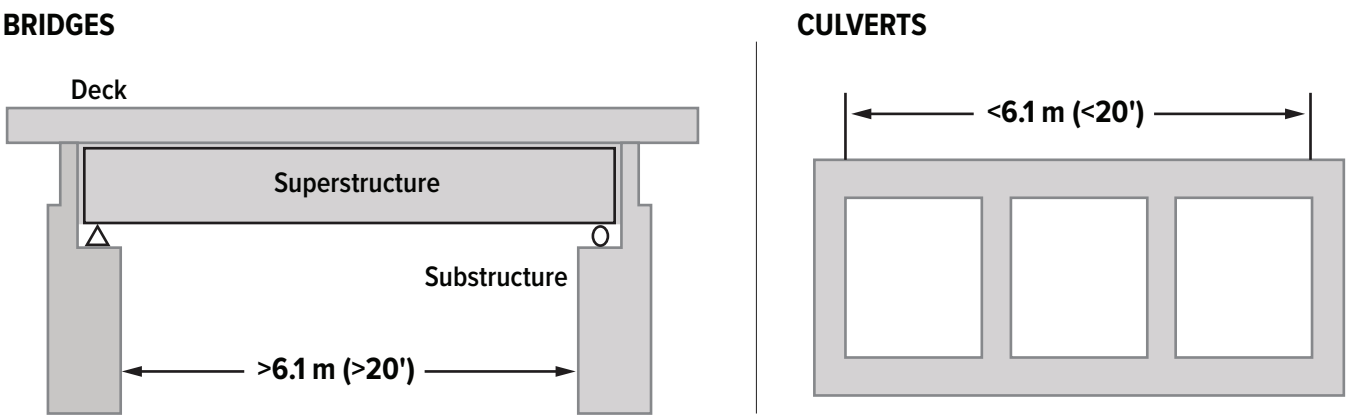


Figure 15 *National Bridge Inspection Rating Scale*

CDOT must establish performance targets for and report bridge conditions according to National Performance Measures standards. FHWA requires state DOTs to report the percentage of bridge-deck area on the NHS in Good condition and Poor condition.

Under the FAST Act, there is a minimum performance level for bridge condition on the NHS in Poor condition (see 23 USC 119 (f)(2)). No more than 10 percent of bridge deck area on the NHS may be classified as Poor. If a state exceeds this minimum condition threshold, the state can lose flexibility on how to use a portion of federal funds. Specifically, the state must then obligate a set amount of funds to eligible projects on bridges on the NHS until the condition exceeds the minimum standard. As of October 2021, 5.1 percent of deck area on the NHS is rated Poor in Colorado—well under the 10 percent threshold.

4.3.3 TARGET SETTING

In addition to the national goals, CDOT maintains internal metrics and goals for bridges in the Department's Policy Directive 14.0 (PD 14.0). PD 14.0 contains broad goals and specific performance targets set by the Transportation Commission that guide the distribution of CDOT's financial resources. Goals in the directive align with MAP-21 National Performance Areas, such as infrastructure condition. The Department's infrastructure goals for all asset categories is "to preserve the transportation infrastructure condition to ensure safety and mobility at a least life-cycle cost." The goal is consistent with risk-based asset management practices.

Table 6 shows the PD 14.0 performance targets for bridges, beginning with the condition measures, followed by related bridge metrics for preservation, risk, and freight movement.

Table 6 *CDOT PD 14.0 Performance Targets*

Performance Area		Performance Measure	Current Performance (2021)	Target	Performance Gap *(Current State vs. Target)*
Condition	National Highway System	Percent of bridge deck area in good condition[1]	37.3%	40%	-2.7 % points
		Percent of bridge deck area in poor condition[1]	5.1%	10%	+4.9 % points
	CDOT-owned bridges	Achieve or maintain the percent of total bridge deck area in good condition at or above	37.1%	40%	-2.9 % points
		Achieve or maintain the percent of total bridge deck area in poor condition below[2]	5.6%	10%	+4.4 % points
Preservation Treatments		Percentage of expansion joints in Fair, Poor, or Severe condition (by length) on CDOT-owned bridges	43.4%	26% or less	-17.4 % points
		Percentage of CDOT-owned bridge deck area that is unsealed or otherwise unprotected	33.8%	35% or less	+1.2 % points
Risk Mitigation		Percentage of CDOT-owned bridges over waterways that are scour critical	5.5%	5.0%	-0.5 % points
		Percentage of bridge crossings over Interstates, U.S. routes and Colorado state highways with a vertical clearance less than the statutory maximum vehicle height of 14-feet-6-inches	2.0%	1.0%	-1.0 % point
		Percentage of bridge crossings over Interstates, U.S. routes and Colorado state highways with a vertical clearance less than the minimum design requirement of 16-feet-6-inches	19.8%	18.0%	-1.8 % points
		Percentage of CDOT-owned bridges with a load restriction	2.4%	0.9%	-1.5 % points
		Percentage of CDOT-owned bridges posted for load	0.4%	0.1%	-0.3 % points

Source: National Bridge Inventory for CDOT 2021

[1] Measures aligned with FHWA National Performance Measures.

[2] Primary measure as the basis for performance modeling and budget setting.

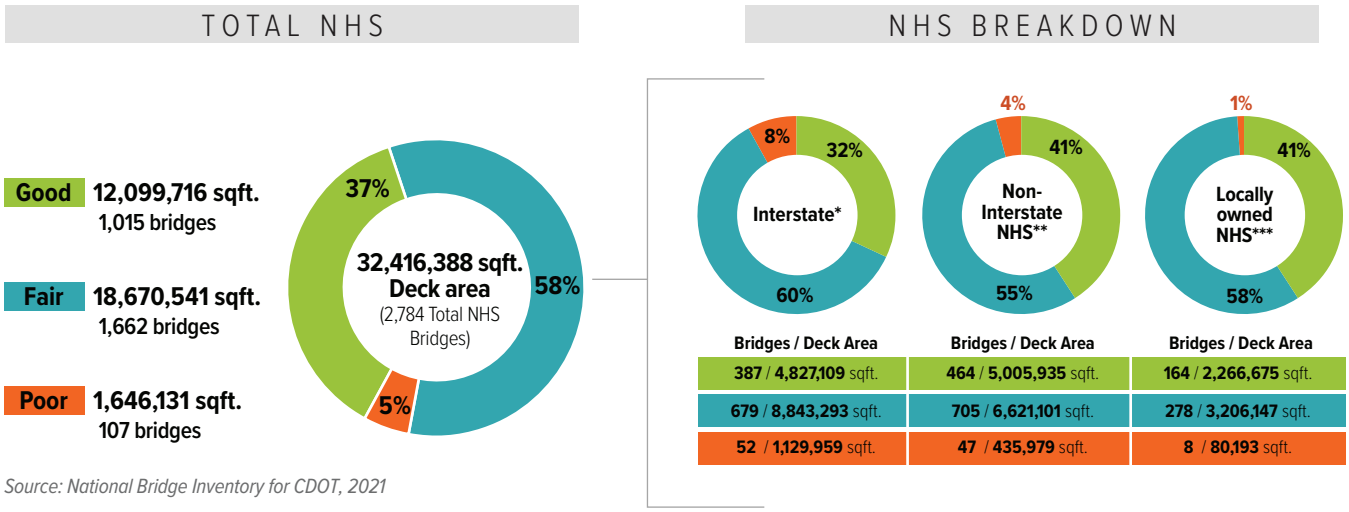
Good and Fair bridges are prioritized for joint and deck membrane treatments during the project-selection process. Ideally, treating joints and decks in a timely fashion will maximize the life-cycle and condition of Good structures at the optimal costs. Poor bridges are addressed primarily through BTE. Scour, height-restricted, and load-restricted structures are monitored as risk metrics. These structures are addressed as funding allows.

4.3.4 CONDITION

Each component of a bridge—deck, superstructure, and substructure is assessed and assigned an NBIS rating. Culverts receive a single overall NBIS rating. If the rating is four or below for any one of the bridge three components or the overall culvert rating, the structure is classified as Poor, or Structurally Deficient. **Figure 16** presents the deck area and percentage of deck area given a Good, Fair, or Poor rating for each classification. About 37 percent of the deck area on the NHS in Colorado is in Good condition as of 2021, while 58 percent of the deck area is in Fair condition. Just 5 percent of the NHS deck area is in Poor condition, which is lower than the FAST Act limit of 10 percent.

Looking at locally owned NHS bridges, 58 percent of the deck area is in Fair condition, with 41 percent in Good condition, and 1 percent in Poor condition. NHS inventory and condition data for Metropolitan Planning Organizations (MPOs) are summarized in **Figure 17**.

Figure 16 *Condition of Bridges on the NHS (2021)*

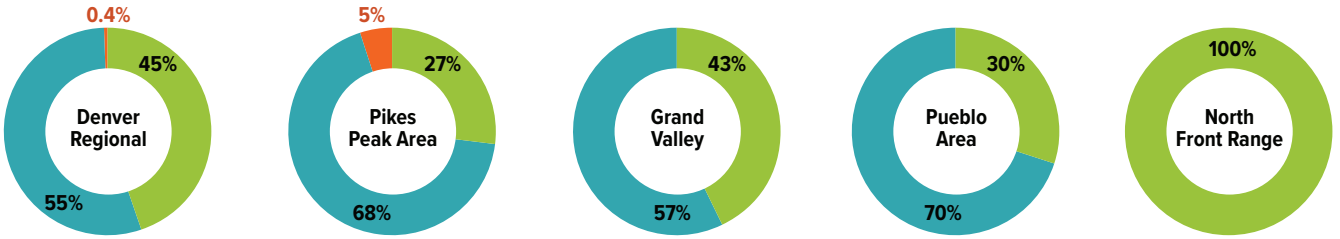


Bridges / Deck Area	Bridges / Deck Area	Bridges / Deck Area
387 / 4,827,109 sqft.	464 / 5,005,935 sqft.	164 / 2,266,675 sqft.
679 / 8,843,293 sqft.	705 / 6,621,101 sqft.	278 / 3,206,147 sqft.
52 / 1,129,959 sqft.	47 / 435,979 sqft.	8 / 80,193 sqft.

Source: National Bridge Inventory for CDOT, 2021

* CDOT-Owned
** CDOT-Owned Only (Excludes Locally Owned Bridges)
*** Includes Toll Roads

Figure 17 *Condition of Locally Owned Bridges on the NHS by MPO (2021). Percentage based on deck area.*



Bridges / Deck Area	Bridges / Deck Area	Bridges / Deck Area	Bridges / Deck Area	Bridges / Deck Area
126 / 1,825,487 sqft.	30 / 360,344 sqft.	5 / 54,259 sqft.	2 / 7,110 sqft.	1 / 19,475 sqft.
187 / 2,208,532 sqft.	81 / 908,394 sqft.	6 / 72,679 sqft.	4 / 16,542 sqft.	N/A
1 / 15,219 sqft.	7 / 64,974 sqft.	N/A	N/A	N/A

Source: National Bridge Inventory for CDOT, 2021

Good Fair Poor

4.3.5 CONDITION TRENDS

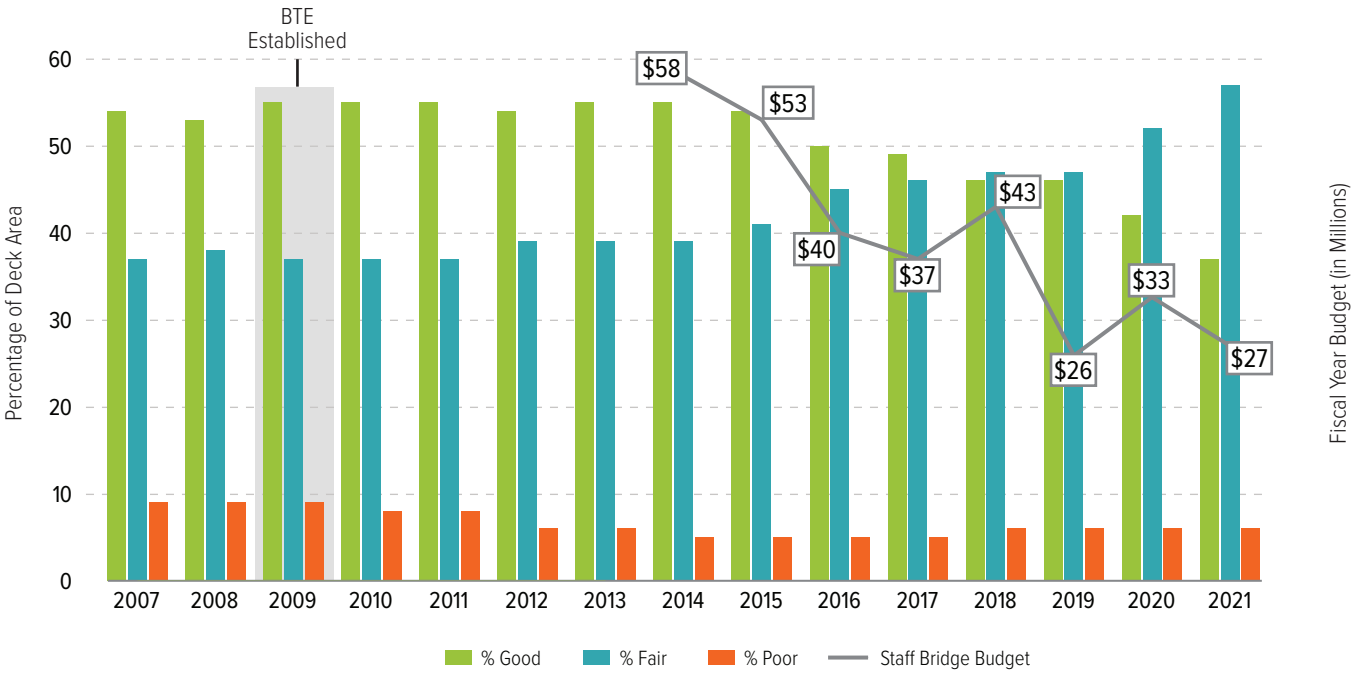
Bridges on the NHS in Colorado are in relatively good condition. However, many structures built in the 1950s or before are past the end of their designed service lives of 50 years. The next 10 years will see the largest number of Colorado's bridges ever meet the end of their designed service lives, resulting in considerable funding needs for replacements and rehabilitations.

Figure 18 shows the percentage of deck area on NHS bridges in Good, Fair, and Poor condition since 2007. Since the formation of BTE in 2009, the percentage of deck area in Poor condition has decreased, while the percentage of deck area in Fair condition has recently begun to exceed the percentage in Good condition. **Figure 18** also presents the historical trends for the bridge-preservation program's spending.

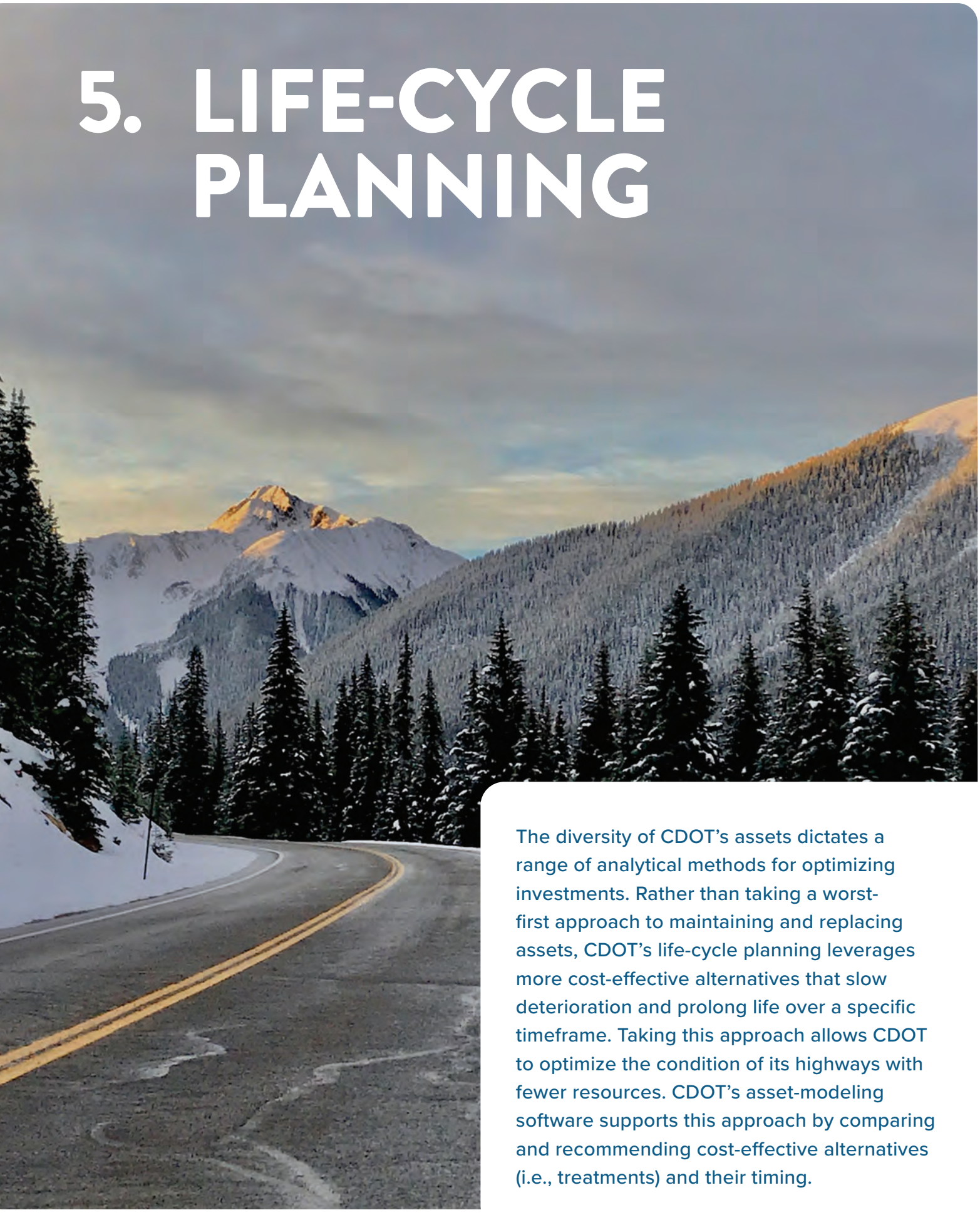
CDOT's $1.2 billion Central 70 project is improving 10 miles along the Interstate and has already replaced one of CDOT's largest poor structures. This bridge, which comprised about one percent of all bridge-deck area in Colorado and almost two percent of total NHS bridge-deck area, fell from Fair to Poor condition in 2019. The Central 70 project has replaced this structure and will replace other Poor bridges that, combined, represented 35 percent of CDOT's Poor rated bridge deck area.

Figure 18 *Condition Trends and Bridge Preservation Program Expenditures for CDOT-Owned Bridges (in Millions)*

With reduced funding for Staff Bridge since 2014, the area of Good bridge deck has decreased, and the Fair bridge deck area has increased. Since the establishment of the BTE in 2009 the area of Poor bridge deck area has decreased.



5. LIFE-CYCLE PLANNING



The diversity of CDOT's assets dictates a range of analytical methods for optimizing investments. Rather than taking a worst-first approach to maintaining and replacing assets, CDOT's life-cycle planning leverages more cost-effective alternatives that slow deterioration and prolong life over a specific timeframe. Taking this approach allows CDOT to optimize the condition of its highways with fewer resources. CDOT's asset-modeling software supports this approach by comparing and recommending cost-effective alternatives (i.e., treatments) and their timing.

5.1 CDOT LIFE-CYCLE PLANNING STRATEGY AND TOOLS

CDOT's life-cycle planning strategy incorporates preventive maintenance, preservation, and rehabilitation activities. As **Figure 19** illustrates, these activities slow the deterioration of an asset and prolong its life. As lifespan is extended, replacement can be delayed. As a result, preservation and rehabilitation strategies can drive down ownership costs.

CDOT develops life-cycle planning strategies for each asset based on the cost and benefits of treatments required to preserve or improve the asset's condition. CDOT then develops treatment recommendations to achieve the best asset performance possible with limited resources.

5.1.1 ASSET INVESTMENT MANAGEMENT SYSTEM

The Department's Asset Investment Management System (AIMS) modeling software uses past performance data, deterioration curves for each asset, and treatment information to predict the future condition of an asset class. AIMS also recommends treatments (e.g., maintenance vs. preservation vs. rehabilitation vs. reconstruction) that will improve asset conditions and optimize the budget allocations to create the best forecasted performance.

By comparing projected performance under different funding levels, the software helps the TAM Program determine how much funding an asset class should receive. For example, the software can show how additional funding will benefit the performance of bridges relative to giving that same funding to the pavement asset class.

AIMS functionality includes:

- Analyzing individual assets
- Supporting target setting
- Optimizing decisions across assets
- Recommending investment strategies

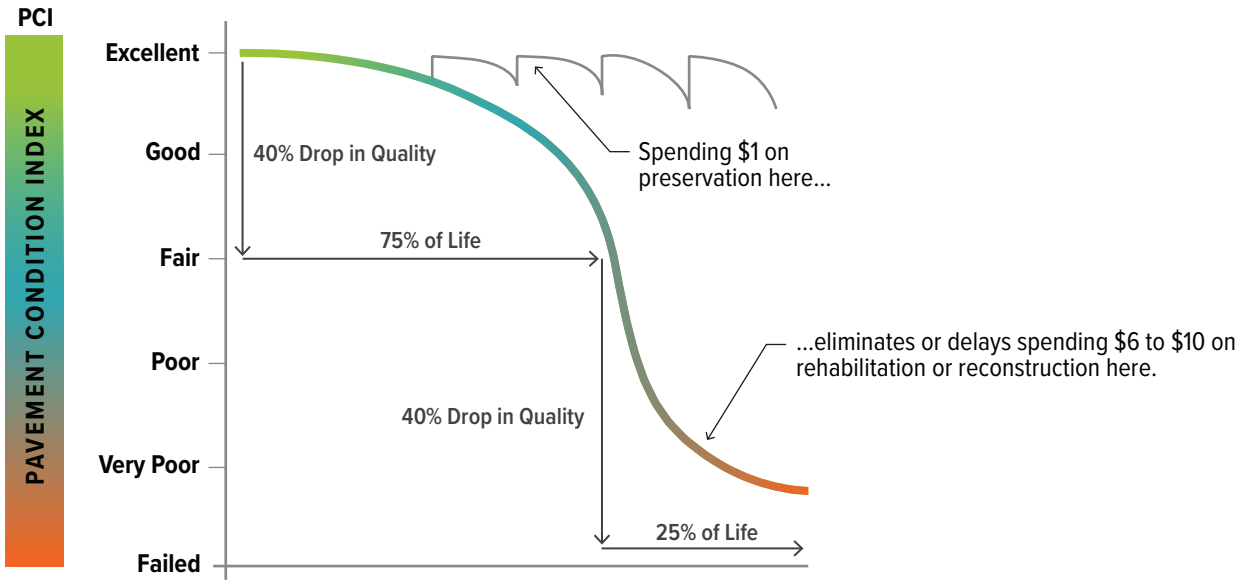
The work associated with AIMS is primarily contracted out, although the PAMB team includes a modeling analyst who helps refine the model, improve data quality and documentation, and interpret model results. CDOT continues to make incremental enhancements and refinements to improve AIMS analyses.

5.1.2 LIFE-CYCLE MANAGEMENT APPROACHES

Because CDOT manages so many asset classes, a range of life-cycle management approaches is required. The Department considers a range of approaches that reflect the criticality of different assets to the asset management, safety, and mobility outcomes it wants to achieve. These life-cycle management approaches include the following:

Figure 19 *Benefit of Pavement Preservation*

This illustration, from FHWA's Pavement Preservation Compendium II, shows the cost-effectiveness of pavement preservation treatments. Costs shown are not specific to CDOT.



Source: FHWA

Resiliency Initiative: Understanding the greenhouse gas impacts of construction materials.

In response to the Buy Clean Colorado Act (HB 21-1303), CDOT is beginning to collect Environmental Product Declarations (EPD's) on eligible materials. An EPD is a document that communicates the environmental impacts of a product or material over a specified life-cycle. This initiative helps CDOT meet the intention of the IIJA and will also inform life-cycle management decisions.

CDOT has chosen to focus EPDs on 32 primary bid items that comprise more than 70 percent of average annual construction expenditures. These items include asphalt, concrete, retaining walls, reinforcing steel, culverts, and guardrail.

CDOT is to use these EPDs to develop a policy establishing maximum Global Warming Potential (GWP) for each eligible material.

- **Condition/Risk-Based:** The condition or risk profile of an asset is measured and used to forecast performance and identify the onset of failure. A condition approach is used to plan treatments for pavements and bridges. A risk-based approach is used for Geohazards.
- **Interval/Age-Based:** Asset performance data and/or manufacturers' suggested life-expectancy estimates are used to establish a time interval representative of the service life beyond which the cost of asset failure outweighs the cost of replacement.
- **Reactive:** CDOT reacts to fix a problem after it has occurred.

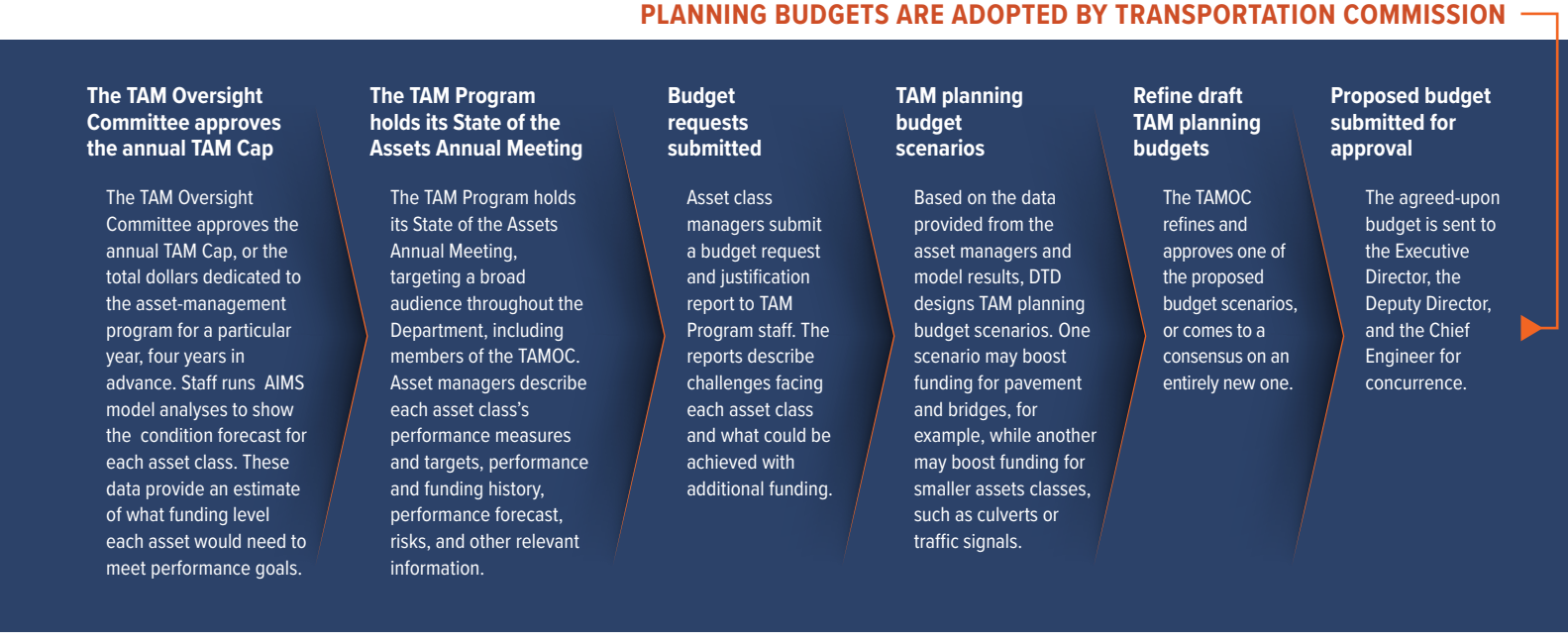
Communicating what approaches are used for which assets creates a consistent understanding of risk.

5.1.3 DEVELOPING PLANNING BUDGETS

Prior to 2021, CDOT held a large, day-long workshop to set the planning budget for each asset class. This involved a presentation on funding needs from teams representing each asset class. Executives, selected Region staff, and Headquarters asset managers then voted on how to distribute asset management funding among the 12 asset classes.

In November 2020, the TAM Oversight Committee (TAMOC) approved a new process by which planning budgets are developed for all asset classes, except maintenance levels of service (MLOS), as presented in **Figure 20**.

Figure 20 *How Planning Budgets are Developed*



5.2 PAVEMENTS LIFE-CYCLE PLANNING

CDOT's pavement life-cycle planning is based on established treatment strategies, informed by the AIMS model. The model performs a life-cycle analysis for various treatment strategies on each highway segment. The benefit of the life-cycle strategy is balanced against cost, and segments with the highest benefit/cost ratio are recommended for funding.

5.2.1 LIFE-CYCLE PLANNING STRATEGIES

The objective of CDOT's asset management program for pavement (i.e., the Surface Treatment Program) is to maintain the quality of pavement on state highways at the highest level possible by allocating resources through a data-driven approach over the life of pavement assets. CDOT achieves this objective through three foundational strategies: preservation first, risk-based prioritization, and integrated decision making (see **Figure 21**).

5.2.2 TREATMENT STRATEGIES

Treatments commonly applied to the pavement network include chip seals, ultra-thin overlays, preventive maintenance, minor rehabilitations, major rehabilitations, and reconstructions. Each treatment type is suitable to address particular distresses. The AIMS model helps the Department determine when a treatment should be triggered.

Figure 21 *Pavement Life-Cycle Planning Strategies*

PRESERVATION FIRST	RISK-BASED	INTEGRATED DECISION MAKING
Conduct More Preventive Maintenance on Pavement	**Prioritize Interstates and High- and Medium-Volume Roadways**	**Achieve Economic Efficiencies by Coordinating the Surface Treatment Program**
» Lower-cost treatments are applied in a timely manner. » High-cost rehabilitation and reconstruction treatments are minimized. » Preventive maintenance adds three to six years of Drivability Life to highway segments. » Preventive treatments prevent moisture infiltration in low-volume roads.	» Risk-based targets are used in guiding investment recommendations. » Different Drivability Life standards are established based on traffic volumes. » Higher performance expectation is required for high-volume roadways. » Treatment selection for a given roadway is based on traffic volume to maximize treatment benefits.	» Delays and congestion due to construction are minimized through coordination among different programs and projects. » Treatments are aligned with any safety and capacity improvement projects. » Project coordination is achieved at the regional and statewide planning levels.

Following the application of a given treatment, condition improvement is expected, which is defined as the increase in the Drivability Life of the pavement segment over the analysis period. The impacts of treatment on pavement condition, and the cost effectiveness of treatments, are both configured in the AIMS model and updated frequently based on historical data. Pavement segments are prioritized in the model based on the benefit-cost ratios and available budget. **Table 7** summarizes CDOT's strategies for addressing pavement and the corresponding benefits in Drivability Life.

Pavement life-cycle cost is driven by the sum of unit costs of each treatment applied over the life of the pavement in question. CDOT has developed cost models and tables that are incorporated into the AIMS model. CDOT uses historical cost-per-lane-mile data from similar projects around the state to determine the cost per square yard of the treatments. This cost does not include non-essential items. **Table 7** shows the high-level pavement treatment cost per mile, the benefit after the application of treatment, and treatment cost effectiveness.

Table 7 illustrates the cost effectiveness of some of the cheaper treatment types. Applying treatment types at the right time is critical to extending the life of a pavement; not doing so leads to reliance on more expensive treatments.

CDOT has developed several inputs and rules to support the AIMS model's analysis for pavement. These inputs include deterioration models based on eight years of historical pavement data, treatment decision trees that determine when a treatment needs to be applied, treatment effectiveness, and treatment unit costs.

In addition to these input parameters, CDOT gathers relevant data from the Regions within the Department to support the analysis. This data enables CDOT to generate both family deterioration curves and site-specific deterioration curves for each condition index used in AIMS. Some of the supporting data CDOT uploads into the AIMS model annually includes:

- The network definition of routes, for undivided and divided routes
- Features located along those routes (intersections, mileposts, etc.)
- Traffic data, including Average Annual Daily Traffic (AADT) and Equivalent Single Axle Load (ESAL) information

Table 7 *Pavement Work Types, Treatment Examples, Costs and Benefits*

Work Type	Example Treatments	Treatment Type	Cost Per Lane Mile	Benefit in Drivability Life (years)	Treatment Cost Effectiveness (per year)
Preservation	Chip seals, ultra thins, microsurfacing, crack sealing, joint sealing, concrete diamond grinding, concrete-slab replacements, and others.	Preventive Maintenance	$52,200	4 to 5	$10,400
		Chip Seal	$56,000	Up to 10	$5,600
		Ultra-Thin Overlay	$149,300	Up to 14	$10,700
Maintenance	Performed By MLOS program.				
Rehabilitation	Minor rehabilitation and major rehabilitation treatments.	Minor Rehabilitation	$261,200	15 to 18	$14,500
		Major Rehabilitation	$447,700	20 to 23	$19,500
Reconstruction	Complete reconstruction/ replacement of the existing pavement.	Reconstruction	$1,052,200	25	$42,100
Initial Construction	Capacity increases, pavement widening for capacity/safety, and horizontal/vertical changes of pavement alignment.				

» Pavement condition data (raw measures and indexes)

» Pavement historical project data

» Pavement historical maintenance

CDOT's deterioration models account for the effect of environmental conditions on the performance (Drivability Life) of pavements. Pavement distresses progress at different rates under varying environmental conditions. Environmental stressors such as precipitation and freeze-thaw cycles impact pavement design and treatment choice. Therefore, CDOT analyzes life-cycle planning strategies with consideration of environmental conditions.

Additional information on the deterioration models, input parameters, and how CDOT configures and conducts pavement analysis in AIMS is documented in *CDOT Asset Investment System – Pavement Asset Management*. **Figure 22** illustrates the key components of AIMS for pavement analysis and the actions taken to configure or update each component.

5.2.3 IMPLEMENTING PAVEMENT LIFE-CYCLE PLANNING

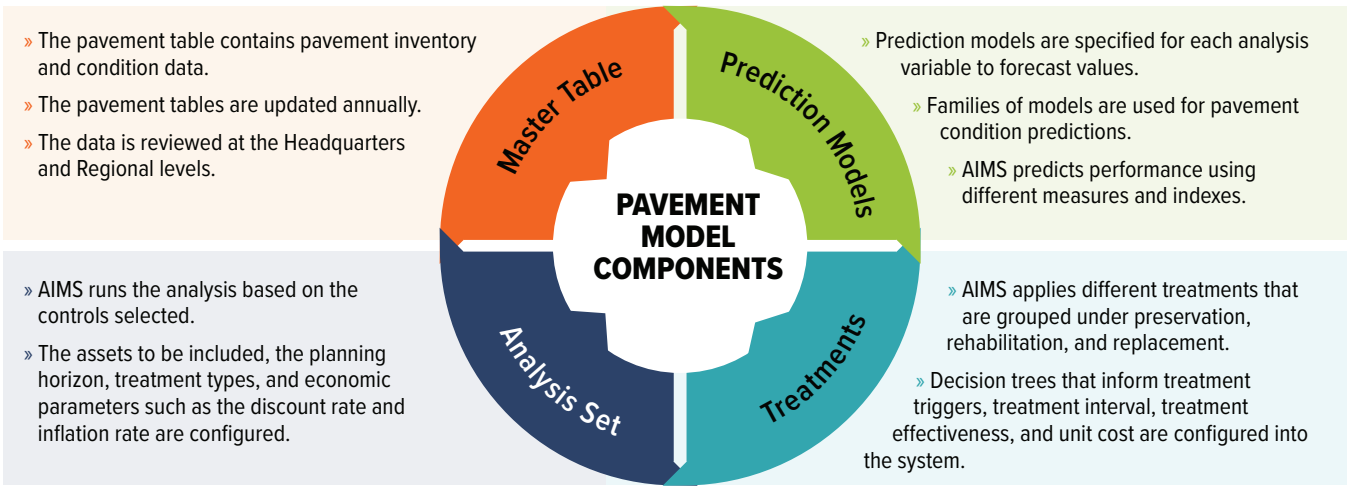
The main goal of asset management is to move away from costly strategies, such as prioritizing replacements of assets in poor condition, to preservation strategies that minimize the whole-life cost of pavements. CDOT achieves this goal by evaluating alternative life-cycle planning (LCP) strategies over the pavement's life. At the network and regional level, CDOT integrates LCP information into asset management decision making, by incorporating LCP analysis results into the development of planned treatments and projects.

CDOT has a formal planning process with its Regions to develop a three- to five-year surface treatment plan. CDOT's life-cycle planning is informed by the Department's pavement-management software. From a network perspective, the software performs a life-cycle analysis of various treatment strategies on each highway segment. The benefit of the life-cycle strategy is balanced against cost. The software analyzes about 3,900 distinct pavement segments and compares the treatment strategies with the highest benefit/cost ratio statewide. CDOT's pavement management team has identified deterioration rates for each pavement section based upon either deterioration curves for a "family" of pavements or a curve specific to each section. As the software models deterioration of an individual segment, it identifies potential treatment options for that segment based on distresses (smoothness, rutting, and cracking) and overall condition (Drivability Life) ratings.

The cost for each potential treatment, or strategy of treatments over time, is calculated as the total dollar cost. The benefit is calculated as an increase to the segment's Drivability Life score over the analysis period, and it includes a traffic-weighting factor. This factor increases the benefit relative to the amount of Annual Average Daily Traffic (AADT) on the highway segment. The benefit of a treatment or strategy on a given highway segment is divided by the cost to determine the benefit/cost ratio. The higher the ratio for a treatment or strategy, the more cost effective it is.

The number of potential treatments or strategies for a pavement segment can range from as few as 21 to as many as 200 treatments over a 20-year analysis period. Such a high number of options are available because of the length of the analysis period, the expected life of the asset, and the combination of

Figure 22 *Components of CDOT's Pavement Model—AIMS*

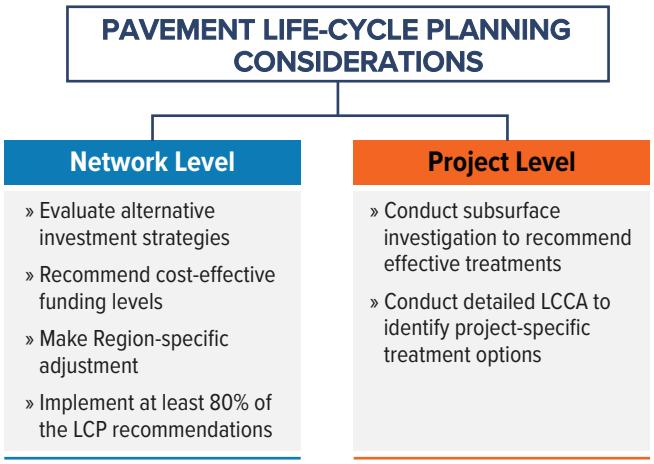


treatment strategies available under different funding scenarios. Assuming the average highway asset has 100 potential treatments or strategies, when all 3,900 segments are iteratively analyzed, the program will have identified 390,000 potential treatments. The software distributes dollars to treatments based on highest benefit/cost ratios and available budget.

CDOT headquarters' pavement-management team builds and maintains the pavement management models and software. Each year's production model is delivered to the Regions for project-level development of the surface treatment project plan. Regions modify their models to account for Region-specific variable and issues. CDOT has a policy that at least 80 percent of pavement projects must match recommendations from the software. This ensures CDOT accounts for life-cycle planning considerations and adheres to optimized pavement treatment selection.

Model treatment recommendations are shared with each of CDOT's Regions, which make Region-specific adjustments based on local knowledge. To support data-driven decisions, CDOT has a policy that at least 80 percent of pavement treatments align with project recommendations from the AIMS model. This policy enables CDOT to account for LCP considerations and to adhere to optimized pavement treatment selection. It also allows the Regions some flexibility when selecting projects.

No model captures every factor that should be considered when choosing a project. CDOT therefore conducts further analysis including pavement-history research, field visits, traffic-data review, and other site-specific analyses to inform the final pavement treatment and project approach. For example, when pavement-material construction costs are estimated to exceed $3 million, a detailed Life-Cycle Cost Analysis (LCCA) for specific treatment options is recommended. While the AIMS model identifies cost-effective treatment categories given site conditions and predicted deterioration, the project-level LCCA compares specific treatment options against each other with the benefit of detailed site conditions, including information from a subsurface investigation. Detailed information on CDOT's LCCA process can be found in CDOT's *Pavement Design Manual*.[4]



CDOT evaluates road surfaces for their AADT and condition (Drivability Life) and then compares whether it would be more cost effective to undertake frequent short-term minor maintenance (e.g., sealing, surface treatments), or to wait for long-term, major treatments (e.g., major rehabilitation). Determining the ultimate strategy for a particular roadway surface would also consider overall CDOT pavement budgets and maintenance work schedules. This project selection process is summarized in **Figure 23**.

5.2.4 INFORMING INVESTMENT SCENARIOS

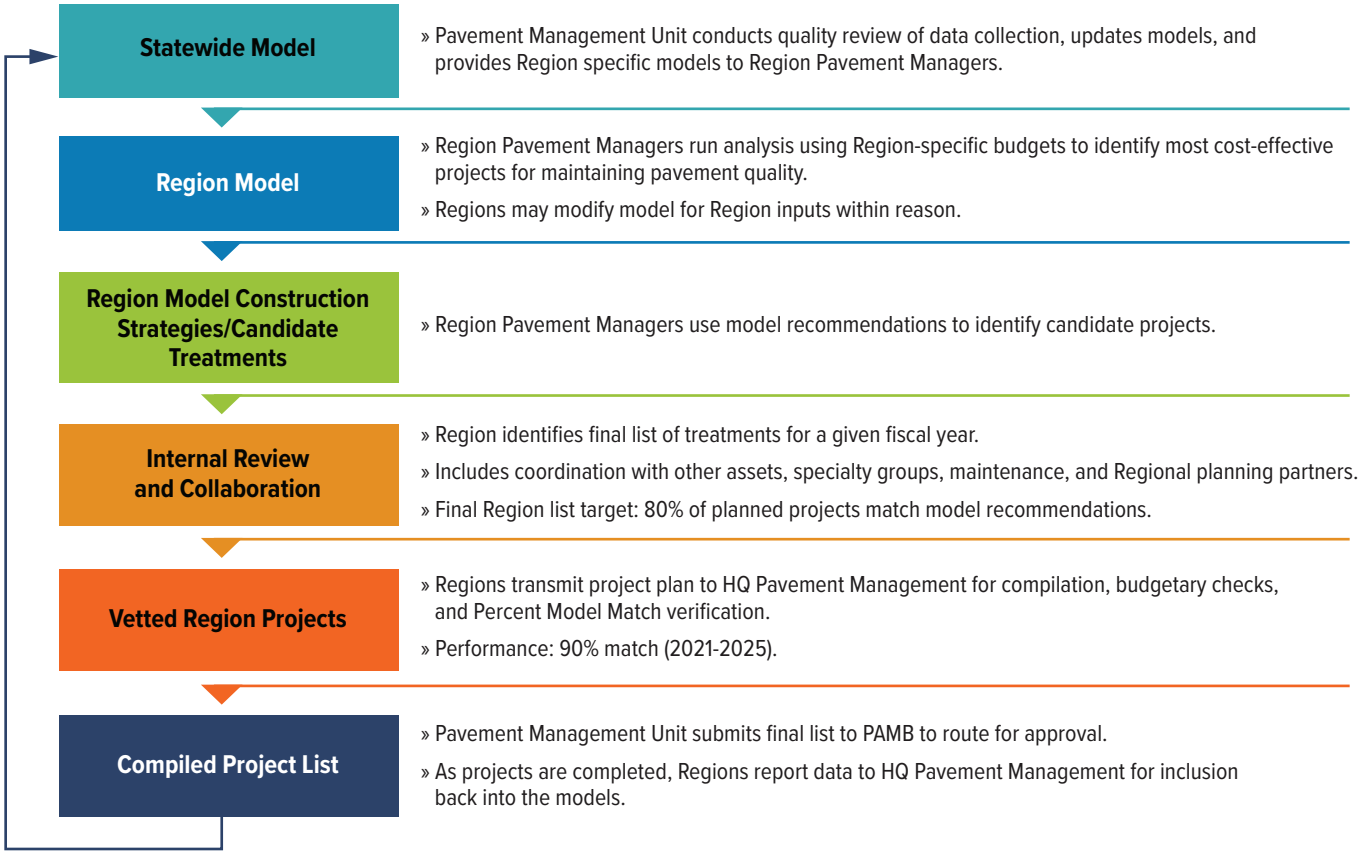
In addition to helping to choose projects, life-cycle planning is a major component of CDOT's budgeting process for its assets. Life-cycle information provides insight into the long-term performance forecast of pavements based on a specific funding scenario, as well as the long-term funding commitment needed to achieve a desired performance level. Life-cycle planning also helps identify the long-term consequence of not taking a given action in the short term. CDOT conducts these analyses using the AIMS model.

Resiliency/Sustainability Initiative: Use of Reclaimed Asphalt

CDOT continues (since 2012) to track the use of reclaimed asphalt in pavements. In 2021, 15 percent of asphalt material was reclaimed.

4 https://www.codot.gov/business/designsupport/materials-and-geotechnical/manuals/2021-m-e-pave-design-manual

Figure 23 *Pavement Project-Selection Process*



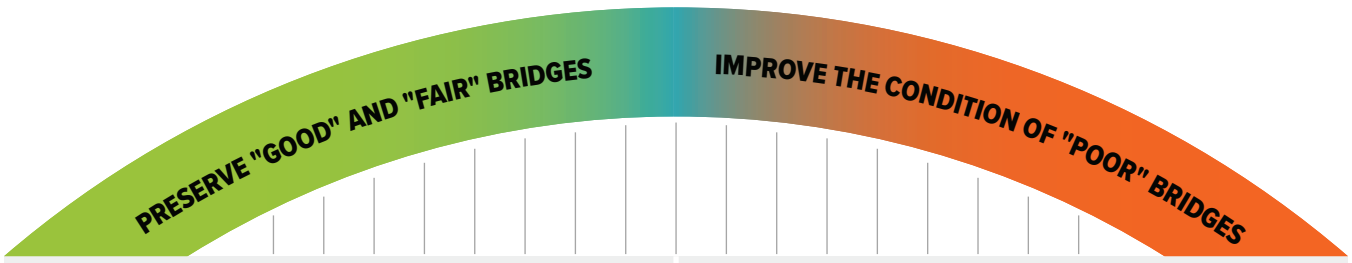
5.3 BRIDGES LIFE-CYCLE PLANNING

As with pavements, CDOT incorporates LCP in its investment strategies for bridges and in developing bridge-related planning budgets and treatment recommendations.

5.3.1 LIFE-CYCLE PLANNING STRATEGIES

There are two main tenets of CDOT's bridge LCP strategy: preserve Good and Fair bridges and improve Poor bridges. CDOT's Staff Bridge unit focuses on Good and Fair bridges, working to maintain healthy bridges instead of waiting for them to get to the point where costly rehabs and replacements are necessary (see **Figure 24**). The BTE improves Poor bridges. The BTE is a government-owned business created in 2009 specifically to perform work on Poor-rated structures.

Figure 24 *Life-Cycle Management Approaches to Bridge* Treatments



- CDOT focuses primarily on preventive maintenance for structures in Good condition.
- Preventive maintenance extends the time a bridge remains in its current condition, minimizing the cost and effort for maintenance activities.
- Rehabilitation activities are performed as needed.

- The number of Poor bridges is reduced through rehabilitation and replacements.
- BTE is the primary entity that replaces (and sometimes rehabilitates) poor bridges. BTE maintains the bridges it has addressed.
- CDOT Staff Bridge inspects, maintains, repairs, and occasionally replaces Poor bridges that have not been transferred to BTE.

5.3.2 TREATMENT STRATEGIES

CDOT's treatment strategy is to apply the appropriate level of effort for bridges in all conditions. Replacement is the costliest and most effort-intensive bridge treatment; CDOT therefore reserves replacements for Poor-rated structures. **Table 8** summarizes CDOT's treatment strategies for addressing major structures.

Table 8 *Bridge Work Types and Treatments*

Work Type	Description	Structure Condition	Work Unit	Cost	Level of Effort	ROI	Example Treatments
Preservation	Activities that prolong the life of the structure by arresting deterioration or re-establishing element protection without changing the condition rating.	Good or Fair	Staff Bridge, Maintenance Sections	Lowest	Lowest	Highest	Bridge rinsing, painting, concrete sealing, joint replacements, deck sealing.
Maintenance	Repairs that prolong the life of the structure by arresting deterioration or re-establishing element protection without changing the condition rating.	Fair	Staff Bridge, Maintenance Sections	Medium	Low	High	Deck repairs, deck sealing, minor patching, crack arrest, joint replacements.
Rehabilitation	Repairs expected to prolong the life of the structure and improve an element- or component-condition rating.	Fair or Poor	Staff Bridge, BTE	High	High	Low	Deck/substructure/ superstructure rehabilitation and split-timber girder rehabilitation.
Reconstruction	Replacement of an existing structure.	Poor	BTE	Highest	Highest	Lowest	
Initial (New) Construction	Construction of a bridge where no bridge has ever been built, such as new interchanges. Widening of the structure to accommodate the addition of any lanes to the existing configuration (e.g., turn lanes, accel/decel lanes, additional general purpose or managed lanes, multi-use pathways). Widening of the structure to accommodate construction phasing. Initial construction does not include shoulder widening or addition of a new shoulder to meet current design standards.						

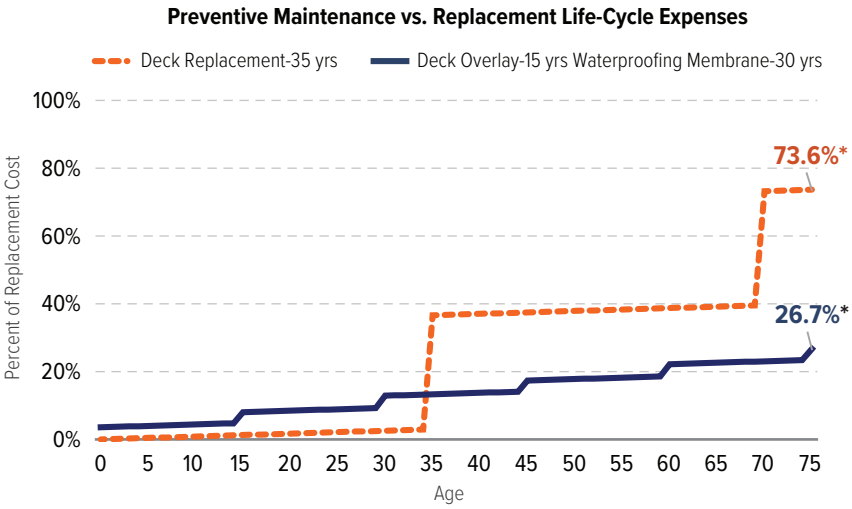
Table 8 illustrates the cost effectiveness of some of the cheaper treatment types. Applying treatment types at the right time is critical to extending the life of a bridge; not doing so leads to reliance on more expensive treatments.

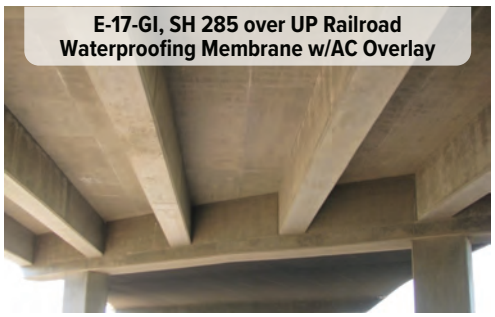
For bridges, LCP is an emerging approach at CDOT to inform the selection of bridge type and preventive actions. Life-cycle planning seeks to identify the total life-cycle cost—per service year and in current dollars—of extending the life of existing structures by performing preventive maintenance. Such maintenance can extend the life of a bridge from an anticipated design service life of 75 years to closer to 100 years. Life-cycle planning recognizes that not all components of a structure will last 75 years without periodic maintenance. Bridge-deck sealing (i.e., applying a waterproofing membrane) and joint replacement are the two activities used in a preliminary LCCA model at CDOT that calculates the annual cost to meet current performance targets for major structures. The model uses historical data for treatment frequency and cost. The unit cost for deck sealing is $40 per square foot, and the treatment frequency is 30 years. The unit cost for joint replacement is $1,500 per linear foot, and the frequency is 15 years. The model is conservative in that it does not account for the current condition of major structures. It is not conservative in that a waterproofing membrane may not last 30 years, and the average bridge joint does not survive 15 years. **Figure 25** illustrates some of this LCCA process for the use of waterproofing membranes for deck sealing. It illustrates reduced costs and improved outcomes achieved by effective bridge-preservation processes.

Along with developing the emerging bridge model, CDOT periodically updates assumptions in its AIMS model, including unit costs, deterioration rates, and more. Along with extensive communication between Regions and CDOT's Staff Bridge unit, analyses from the new bridge model and AIMS may help identify future bridge candidates for replacement, repair, rehabilitation, and preservation.

Figure 25 *Bridge Deck Preservation, Life-Cycle Cost* Comparison

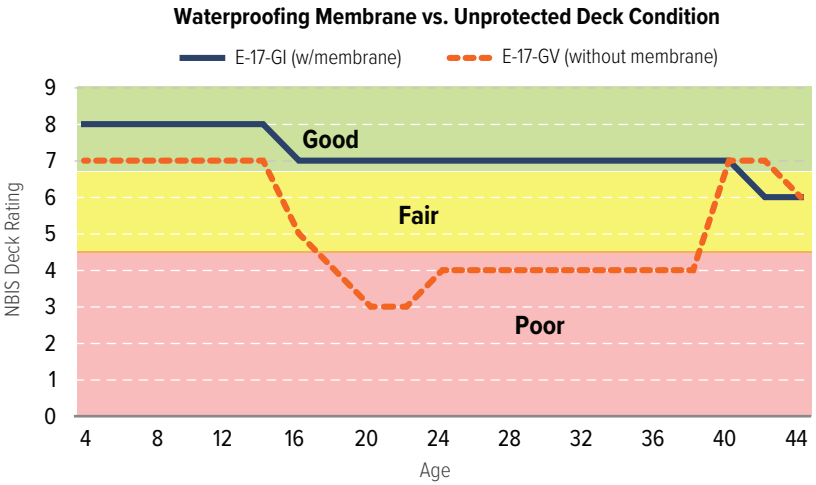
Effective bridge preservation techniques can save almost 50 percent of bridge replacement costs over a 75-year analysis period.





Year Built: **1972**
Photo: **2008**, Age: **36**, Deck Rating: **7**

* Expressed as percentage of total bridge replacement costs.



Year Built: **1967**
Photo: **2005**, Age: **38**, Deck Rating: **4**

5.3.3 IMPLEMENTING BRIDGE LIFE-CYCLE PLANNING

The Staff Bridge Branch provides project support to the Regions by collecting bridge data, assessing bridge conditions, and grouping bridges into recommended replacement, repair, or preventive maintenance categories.

The BTE develops a prioritization plan for bridges rated Poor and takes ownership and maintenance responsibilities for bridges that are rehabilitated or replaced with BTE funding.

Throughout the project-selection process, the Regions provide invaluable local input regarding project needs and desires. Ultimately, the Regions identify candidate structures to treat with budgeted asset management funds and establish preventive maintenance or repair budgets.

Resiliency Initiative: Focused Scour Inspections

Each spring the Staff Bridge Branch provides direction to Regions on 'scour watch' for bridges. This includes the need to focus on structures near recent wildfire locations to examine for damage from post-fire debris flows.

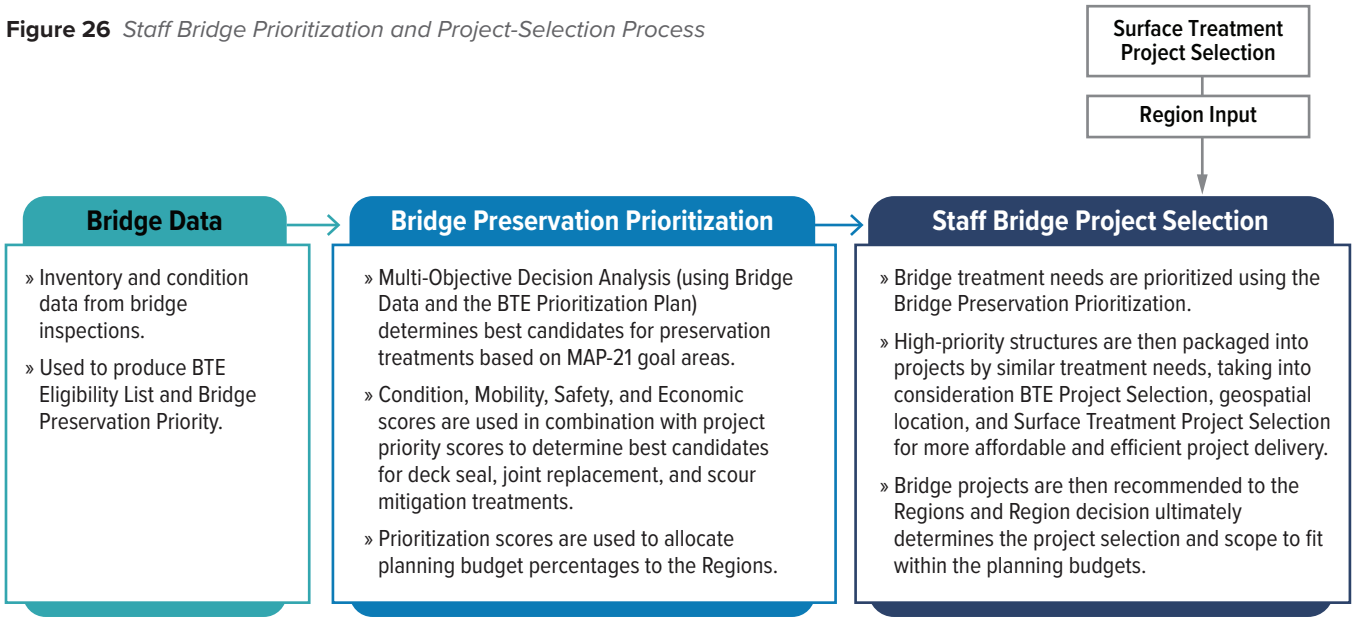
The implementation of bridge projects is formalized through the Structure Asset Management (SAM) Plan, which incorporates the Structure Preservation Program and BTE project prioritization lists into a final, four-year asset management plan. The SAM Plan is developed by first identifying treatment needs for the full structures inventory, and then developing cost estimates for those treatments. Opportunities

to combine work are identified, and Bridge and Surface Treatment program lists and priorities are coordinated. All potential future projects are aggregated based on location, proximity, and work type. Projects that will target high asset-priority scores and move performance metrics with a high return on investment are then identified. This process includes coordination between BTE planned rehabilitation/replacement projects and bridge maintenance/preservation to ensure all treatments achieve the expected life-cycle. **Figure 26** provides a summary of the CDOT-owned bridge project-selection process.

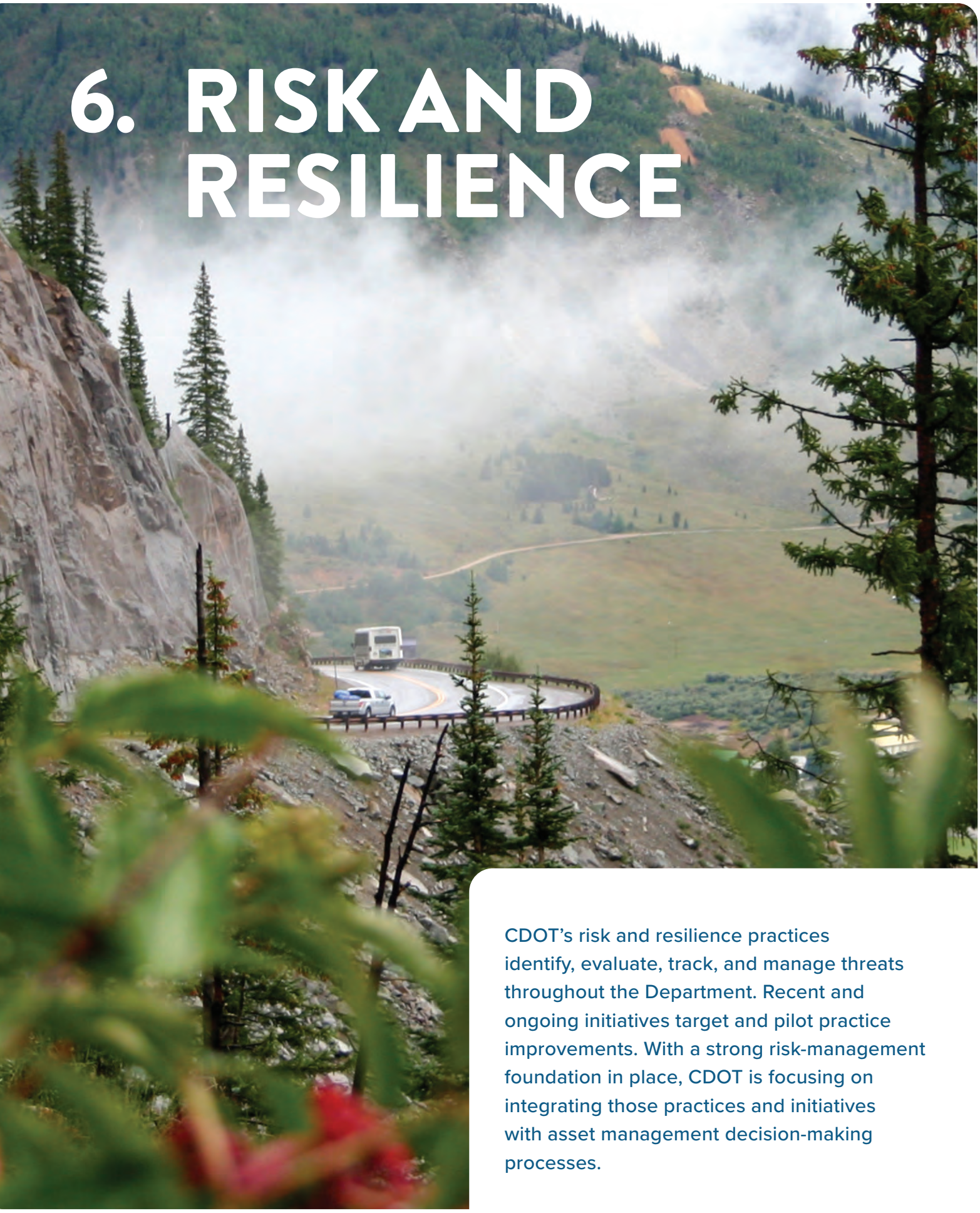
5.3.4 DEVELOPING INVESTMENT SCENARIOS

As with pavements, CDOT informs its overall bridge budgets with life-cycle considerations. Estimated annualized costs for appropriate life-cycle treatments on CDOT's bridges far outweigh anticipated budgets for the Staff Bridge Branch. This makes it critical that every dollar spent maximizes the value CDOT achieves in improving its bridge assets.

Figure 26 *Staff Bridge Prioritization and Project-Selection Process*



6. RISK AND RESILIENCE



CDOT's risk and resilience practices identify, evaluate, track, and manage threats throughout the Department. Recent and ongoing initiatives target and pilot practice improvements. With a strong risk-management foundation in place, CDOT is focusing on integrating those practices and initiatives with asset management decision-making processes.

6.1 COLORADO CONTEXT

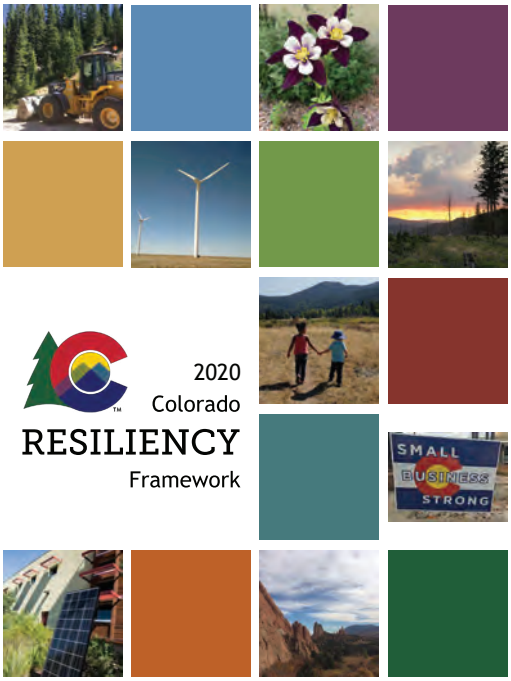
CDOT's approach to resilience was motivated in large part by several natural disasters and man-made threats:

- Colorado experienced significant flooding in 2013, which devastated its Front Range region. The flood-recovery process took CDOT several years.
- Several of the state's most destructive wildfires in history occurred in 2012 and 2020 and contributed to a heightened awareness of the need for resiliency.
- A significant cyber-attack against CDOT in 2018 pushed the agency to bolster resiliency to man-made threats.

The State of Colorado defines resiliency as "the ability of communities to rebound, positively adapt to, or thrive amidst changing conditions or challenges—including disasters and climate change—and maintain quality of life, healthy growth, durable systems, and conservation of resources for present and future generations."

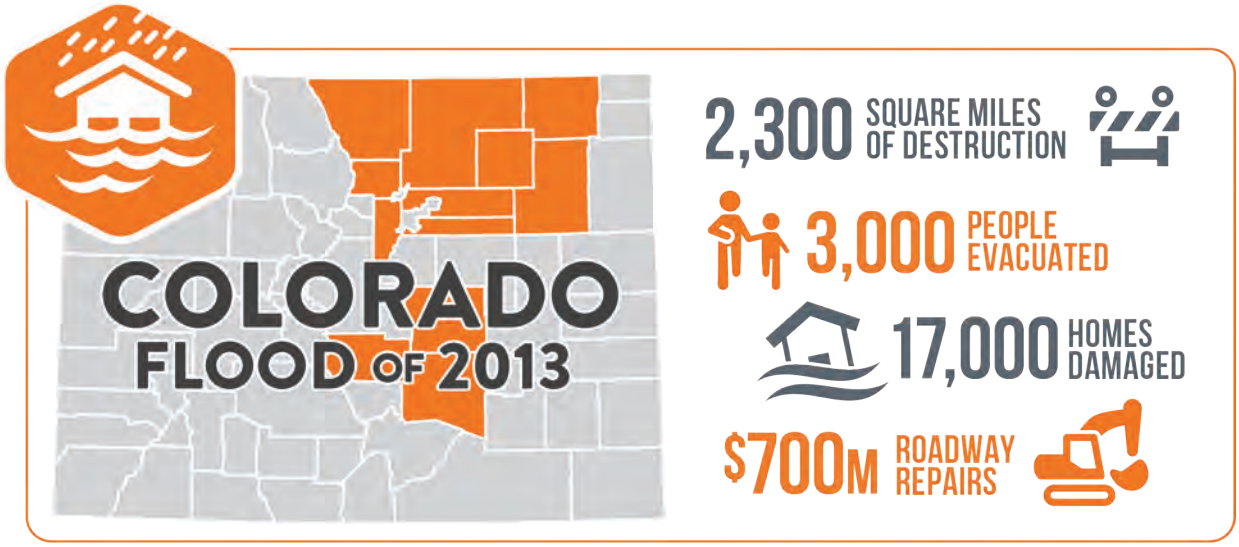
Colorado follows a statewide resiliency plan known as the *Colorado Resiliency Framework*.[5] The Resiliency Framework was adopted in 2015 and updated in 2020. This plan looks at natural threats and disasters in Colorado, including floods, droughts, earthquakes, tornadoes, wildfires, and landslides.

The Resiliency Framework serves two purposes: to show a commitment from the State to identify and implement strategies to increase resiliency, and to outline guiding principles and tools for community stakeholders and a commitment to partnership and action.



One of CDOT's first resiliency initiatives was a Risk and Resilience Pilot in 2015, focused on assessing vulnerability of assets located along Interstate 70. The Department analyzes the criticality of roadways, as described in the 2015 pilot, and is exploring the use of criticality in the project-prioritization process.

CDOT has established a Resiliency Working Group as well as an Executive Oversight Committee, which are implementing a Resiliency Integration project across all aspects of CDOT operations. Furthermore, the Department has produced a manual that can be used as a standalone document to conduct a risk and resiliency analysis on assets.



5 https://www.coresiliency.com/colorado-resiliency-framework

6.2 RISK AND RESILIENCE AT CDOT

CDOT's risk-management approach focuses on planning and managing vulnerabilities; CDOT's resilience approach focuses on recovery and adaptation.

In November 2018, CDOT's Transportation Commission adopted Policy Directive 1905.0, Building Resilience into Transportation Infrastructure and Operations. The directive established the CDOT Resilience Program and directed CDOT to incorporate resilience into strategic decisions about transportation assets and operations. This has positioned CDOT well to meet federal requirements to consider extreme weather and resilience as part of life-cycle cost and risk management, as defined by 23 U.S.C. 119(e)(4)(D).

When the Risk and Resilience Program was created, the focus was on recovering from the 2013 flood event and dealt more with how CDOT recovered in a way that was more adaptable to extreme events. The program more recently has focused on how to harden CDOT's organization and assets for future events, in particular where it makes sense from a benefit/cost perspective. The Colorado floods of 2013 and other events also have led CDOT to begin prioritizing and adopting efforts to address climate-change risk. CDOT has recently taken on various efforts to better understand climate impacts to CDOT's system and operations, including a 2021 study on how changing climate and extreme weather impact geohazards in Colorado.

The Department has defined three cornerstones for considering risk and resilience in its asset management program. These include:

1. **Enterprise Risk Management.** An approach to managing risk across various levels—including agency, programmatic, and project/activity levels.
2. **Defined Risk Process.** The development of CDOT's risk register to establish risk-management priorities across the Department.
3. **Risk and resilience as part of life-cycle planning and life-cycle cost analysis.** A comprehensive decision-making process that includes risk management and resilience as a part of budget setting and treatment selection. This also applies to the identification and treatment of twice-damaged assets (as required under 23 CFR 667).

These cornerstones are described in more detail in the following sections.

6.3 ENTERPRISE RISK MANAGEMENT

CDOT uses an enterprise-wide approach to manage risks, from the Department-wide level down to the activity level. Specifically, CDOT incorporates four levels of risk management into its program:

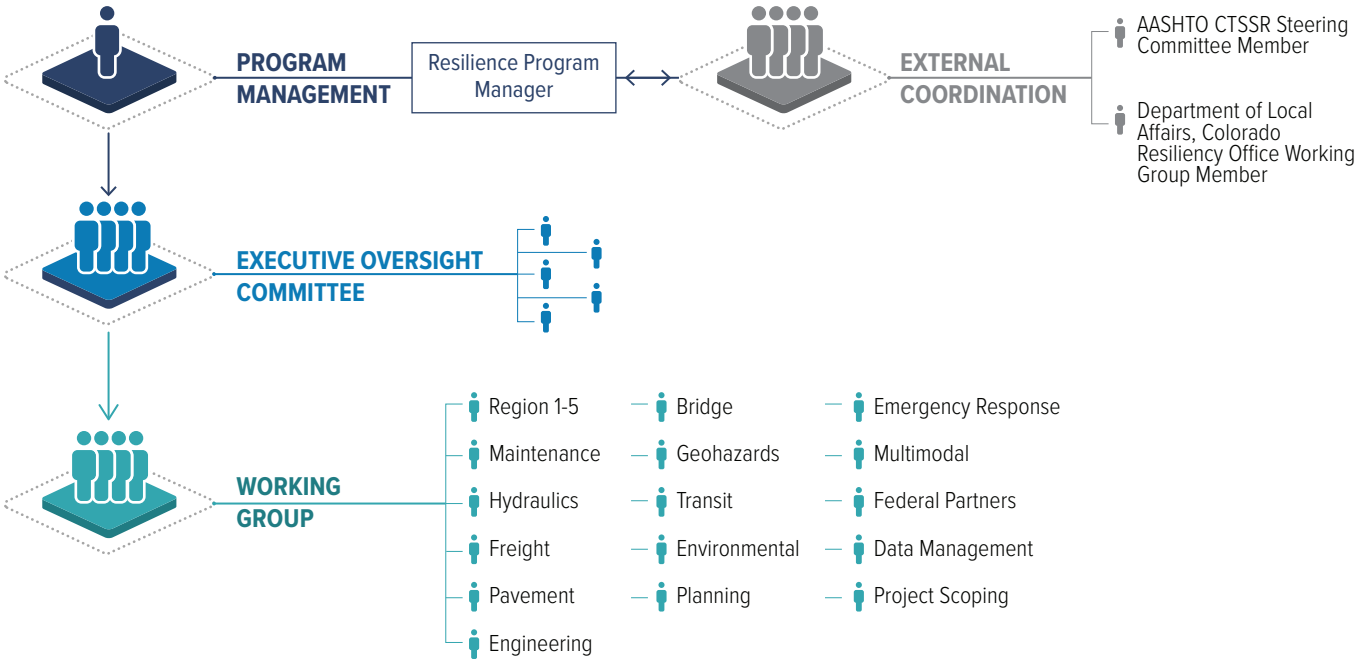
- **Enterprise (Strategic, Corporate)**—Threats that affect mission, vision, and overall results of the asset-management program. Examples include politics, public perception, reputation, and levels of available revenue.
- **Program (Business Line)**—Threats that affect CDOT's ability to deliver projects and meet targets within a program. These may include organizational and systemic issues as well as revenue and economic uncertainties that cause delays. These causes are not related to any specific projects. Examples include project-delivery threats, revenue uncertainties, cost-estimating processes, revenue and inflation projection inaccuracies, construction cost variations, materials price volatility, data quality, and employee retirements.
- **Project**—Threats that affect the cost and schedule to deliver projects throughout the agency. Examples include shortages in material supplies that cause a delay in the project schedule, and unexpected increases in materials costs that increase the overall project budget.
- **Activity-Level**—Threats that affect the ability of an asset to perform its function, assessed against the likelihood of the asset failing (asset condition) and the consequence to CDOT and/or users if the asset were to fail (asset criticality). For example, a bridge that is Structurally Deficient has a higher probability of failing than a bridge that is not. And the failure of a signal located at a major interchange could cause major delays to system users.

6.3.1 RISK AND RESILIENCE MANAGEMENT

CDOT's Risk and Resilience Program is managed by the Performance and Asset Management Branch. The program focuses on developing tools, processes, and projects that advances CDOT resilience practice. The Risk and Resilience Program structure is presented in **Figure 27**.

While outside of the Risk and Resilience Program structure shown in **Figure 27**, the TAM Working Committee considers risk in the TAM program as part of its responsibility.

Figure 27 *Risk and Resilience Program Organization Structure*



6.4 CDOT'S RISK-MANAGEMENT PROCESS

CDOT's risk management process (**Figure 28**) has been guided by documents including the American Association of State Highway and Transportation Officials' (AASHTO) Guide for Enterprise Risk Management, and the International Organization for Standardization (ISO) 31000 Risk Management guidelines. Whenever possible, CDOT sought to incorporate ISO 31000 processes for risk management and associated nomenclature. ISO guidance includes identifying sources of threats, causes, areas of impacts, and potential consequences.

6.4.1 RISK ASSESSMENT

CDOT's approach to evaluating and prioritizing risks includes assessing likelihood, consequence, vulnerability, and priority. The TAM Working Committee and other Department experts in 2022 updated scores for these variables for all threats in the risk register. This includes the top 10 enterprise

Figure 28 *CDOT Risk Management Process*

risks as well as risks to each of CDOT's 12 asset classes. CDOT also added and scored new threats, where applicable.

Calculating of Risk Scores

CDOT incorporates three factors in scoring its risks: threat likelihood, consequence of impact, and vulnerability. Specifically, the risk formula is as follows:

Risk Score = T x C x V

T = Threat likelihood (probability) event will occur

C = Consequences and consideration of risk event

V = Vulnerability of CDOT to risk event or consequences; this can also be seen as the probability that estimated consequence will be realized

Risk scores under this formula range between one and 156.25. The broad scoring range offers more precision in ranking events because it decreases the likelihood of repeat scores. Each component of the overall risk score is discussed below.

Threat Likelihood

Threat likelihood (T) is the probability that a threat event will occur, not its potential of impact to CDOT. This variable is based on expert opinion and historical and predictive analysis of the frequency of the event (i.e., annually, every 10-20 years, every 50 or more years, etc.) and assigned a numeric value from one to five based on a scaling rubric. **Table 9** illustrates the threat-likelihood scoring rubric, where one represents the lowest threat and five represents the highest.

Consequence and Consideration

Consequences and considerations (C) are impacts or results directly caused by a threat event. In the CDOT risk register, consequences are large-scale direct impacts that can be qualified and quantified. Considerations are results that may have an impact, but the level of impact is unknown.

There are four consequence variables for which CDOT assigns a value of one to five, with one being low or no impact, and five being severe impact. The four variables are:

- **Safety**—event causes crashes, injuries, fatalities, or property damage (non-CDOT owned).
- **Mobility**—event affects access for the traveling public, commerce, etc.
- **Asset Damage**—event causes physical damage to CDOT-owned assets.
- **Other Financial Impacts**—event causes financial impacts to CDOT, or financial impact on the community or overall economy, etc.

Table 9 *Threat Likelihood Scoring Rubric*

Level	Descriptor	Description	Annual Probability Range	Probability
1	Low	50+ years between events	<2%	1.0%
2	Medium - Low	20 to 50 years between events	2% to 5%	3.5%
3	Medium	5 to 20 years between events	5% to 20%	12.5%
4	Medium - High	1 to 5 years between events	20% to 100%	40.0%
5	High	Once annual occurrence or greater	100%	99.0%

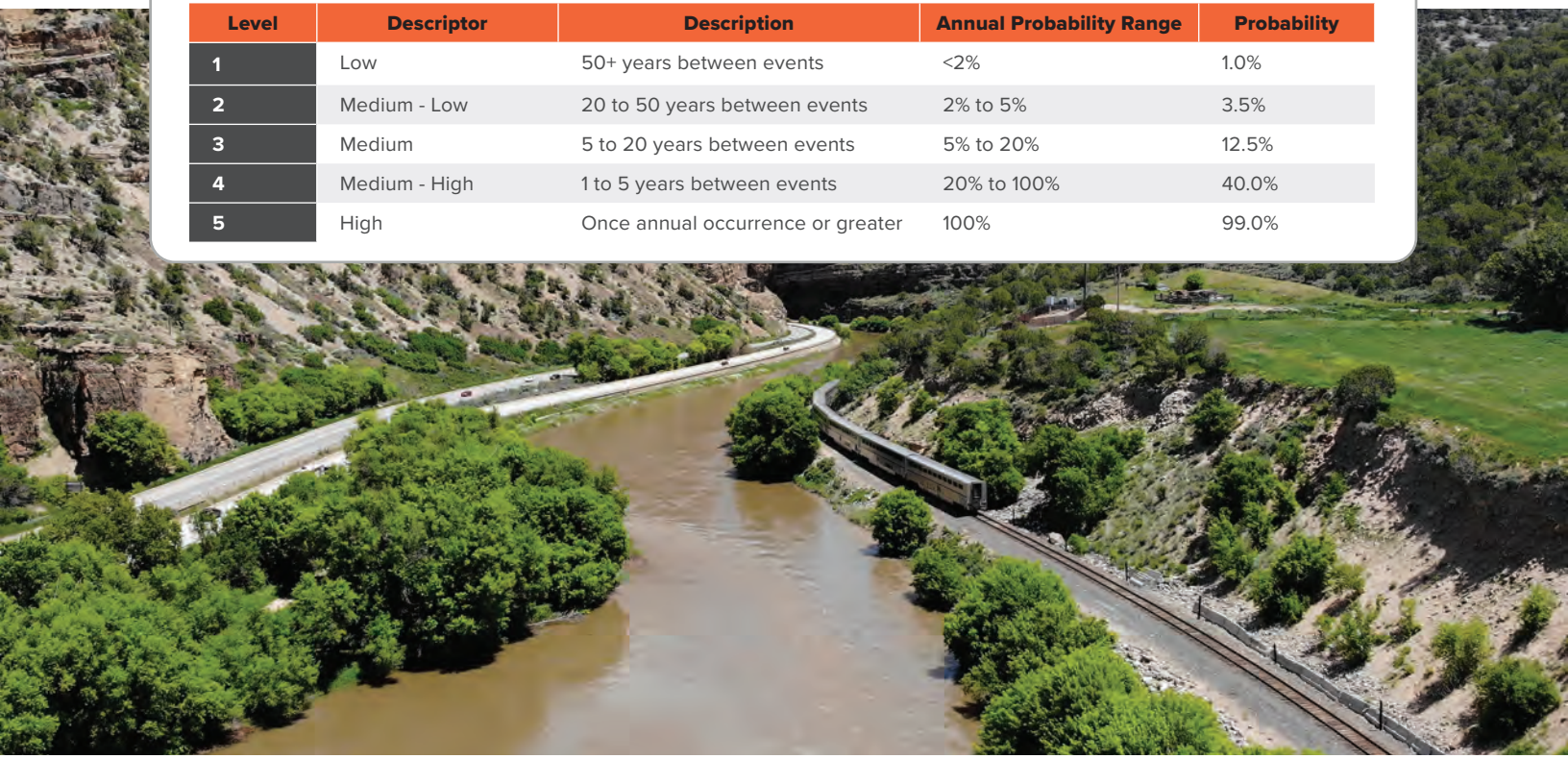


Table 10 illustrates the consequence and consideration scoring rubric.

Table 10 *Consequence and Consideration Scoring Rubric*

Level	Descriptor	Description	Cost Range for Event	Set Safety Cost for Event
Safety				
1	Negligible	Negligible safety hazard	<$100K	$50,000
2	Minor	Minimal safety hazard	$100K to $500K	$300,000
3	Major	Likely minor injuries	$500K to $2M	$1,250,000
4	Critical	Likely major injuries	$2M to $10M	$6,500,000
5	Catastrophic	Likely fatalities and major injuries	>$10M	$20,000,000
Mobility				
1	Negligible	Situation affects a small area (neighborhood or town) and/or small number of travelers for a short time (minutes).	<$100K	$50,000
2	Minor	Situation affects a small area (neighborhood or town) and/or small number of travelers for a moderate time (hours).	$100K to $500K	$300,000
3	Major	Situation affects a small area (neighborhood or town) and/or small number of travelers for a sustained period (days-weeks).	$500K to $2M	$1,250,000
4	Critical	Situation affects a large number of travelers for a short period (minutes-hours).	$2M to $10M	$6,500,000
5	Catastrophic	Situation affects a large number of travelers for a sustained period (days-weeks).	>$10M	$20,000,000
Asset Damage				
1	Negligible	Minimal or cosmetic damage	<$100K	$50,000
2	Minor	Minor damage requiring repair	$100K to $500K	$300,000
3	Major	Moderate damage requiring repair	$500K to $2M	$1,250,000
4	Critical	Extensive damage requiring significant repair or replacement	$2M to $10M	$6,500,000
5	Catastrophic	Destroyed or large-scale damage requiring replacement	>$10M	$20,000,000
Other Financial Impacts				
1	Negligible	Negligible financial impact	<$100K	$50,000
2	Minor	Minor financial impact	$100K to $500K	$300,000
3	Major	Major financial impact	$500K to $2M	$1,250,000
4	Critical	Critical financial impact	$2M to $10M	$6,500,000
5	Catastrophic	Catastrophic financial impact	>$10M	$20,000,000

As mentioned, considerations within the register are impacts that are difficult to quantify. There are five consideration variables in the register:

- **Funding**—Does CDOT have adequate funds to deal with the risk event and potential impacts? Could the event affect future agency funding?
- **Insurance—**Do current levels of insurance cover potential impacts (e.g., personal injury, property damage, fines, or lawsuits)?
- **Regulatory—**Do federal, state, or local regulations inform CDOT planning and response to a risk event? What penalties exist for non-compliance?
- **Political—**Would the risk event spark political interest or response?
- **Reputation—**Would the event affect CDOT's reputation with relevant stakeholders (e.g., the media, traveling public, or taxpayers)?

CDOT assigns a value of 0.05 to each consideration relevant to the risk in question. Under the risk calculation, consequences and considerations are calculated independently. They are then combined using an algorithm to give an overall (C) score.

C = Os × [(Ss + Ms + Ds + Fs)/4]

Os = Considerations Value = 1 + (0.05 × [Number of Selected Considerations])

Ss = Safety Value

Ms = Mobility Value

Ds = Asset Damage Value

Fs = Other Financial Impact

Vulnerability

The vulnerability (V) variable is a comparison of the potential impacts of a natural or manmade event to the robustness of the asset and system, or to CDOT response planning. This variable helps CDOT evaluate risk exposure to certain events, by considering previous resiliency efforts, asset engineering, and other risk management strategies. Asset managers assign a numeric value from one to five for vulnerability, with one representing low vulnerability to the event (i.e., strong preparedness or resiliency), and five representing severe vulnerability. **Table 11** illustrates the vulnerability scoring rubric.

Adding the vulnerability variable changed CDOT's understanding of the priority of threat events. Many asset programs have taken steps to prepare for events with a high likelihood of severe consequences. However, adding the vulnerability variable resulted in a decrease to overall risk scores when compared to previous evaluations. Conversely, risk scores rose for certain events that are infrequent or have low impacts.

6.4.2 MANAGING RISK

CDOT's risk register provides preferred approaches to risk management by identifying combinations of five strategies to manage top-priority risks. These strategies include:

- **Treating the risk**—taking action to reduce the chance of the risk occurring or lessening impacts.
- **Tolerating the risk**—accepting the current risk profile and planning for appropriate response if the risk event occurs.
- **Transferring the risk**—allowing another agency or third party to take on the risk exposure instead of CDOT (e.g., insurance).
- **Taking advantage of the risk**—seizing opportunities, such as by using unexpected revenue to improve the transportation network.
- **Terminating the risk**—taking action to eliminate a risk event or impacts.

Table 11 *Vulnerability Scoring Rubric*

Score	Level	Description
1	Very low	» Established risk management process(es) exist for event » CDOT responses and contingency plans already in place, and are fully tested » Asset engineering design or asset condition ensures full functionality » Previous resilience efforts provide a high degree of protection
2	Low	» Established risk management process(es) mostly exist for event » CDOT responses and contingency plans already in place, but with limited testing » Asset engineering design or asset condition ensures mostly full functionality » Previous resilience efforts provide a moderate degree of protection
3	Medium	» Risk management process(es) for event being fully developed » CDOT responses and contingency plans partially in place, with limited or no testing » Asset engineering design and asset condition ensure only partial functionality » Previous resilience efforts provide a low degree of protection
4	High	» Established risk management process(es) for event in early development » CDOT responses and contingency plans in early development, with no testing » Asset engineering design and asset condition provide little assurance of functionality » Previous resilience efforts provide a very low degree of protection
5	Very High	» Established risk management process(es) do not exist for event » No CDOT responses and contingency plans being developed » Asset engineering design and asset condition will not assure functionality » Previous resilience efforts provide no level of protection

In addition to these response approaches, CDOT has been integrating additional response analyses to its risks. For example, CDOT recently adopted a mitigation plan for Interstate 70 in Glenwood Canyon (see Section 6.8.3), looking at ways to reduce annualized risk and improve system resilience for specific assets at specific price points (e.g., replacing existing rockfall fences with more and higher capacity fences). The Department also has recently adopted benefit/cost calculations to assess alternative mitigation measures and reductions of annualized risks, expressed in dollars, to help justify mitigation plans to identified risks.

6.4.3 MONITORING RISK

CDOT actively monitors its risks, working in coordination with the various asset programs and divisions. The purpose of such monitoring and review, as defined by ISO 31000, includes:

- Ensuring risk-control mechanisms are effective and efficient in design and operation.
- Obtaining further information to improve risk-assessment procedures.
- Analyzing lessons learned from events (including near misses), changes, trends, successes, and failures.
- Detecting changes in context (external and internal), including changes to risk criteria and the risk itself, which requires revision of currently established risk treatments and priorities.
- Identifying emerging or previously overlooked threats.

CDOT has designed the risk register to identify and monitor top-priority risks. The register will be updated regularly as contexts and circumstances change, or as risk-management efforts influence overall risk exposure. CDOT will be establishing roles and responsibilities for risk management within CDOT and individual asset groups.

6.5 ENTERPRISE-LEVEL RISKS

CDOT maintains both an enterprise-level risk register and individual risk registers for each asset class, identifying risks that pose a threat to the Department. The risk register is maintained by the TAM Working Committee, according to the approach outlined in Section 6.4. **Table 12** lists the top 10 enterprise-level risks in 2022 and CDOT's overarching approach to responding to those risks.

Table 12 *CDOT Enterprise-Level Risk Register*

Threat/Opportunity	Risk Statement	Risk Score*	Risk Management Strategy
Flood	There is a risk that flooding occurs leading to asset/route damage that causes mobility and safety impacts as well as increased asset management cost.	68 (T)5 * (C)4.5 * (V)3	Treat by implementing design standards; following agency continuity of operations plan; maintaining incident command center management structure; maintaining an Office of Emergency Management (OEM). Use tools and processes developed under the resilience program to identify high risk assets and corridors for focused analysis.
Post-Fire Debris Flow	There is a risk that post-fire debris flow occurs leading to asset/route damage that causes mobility and safety impacts as well as increased asset management cost.	48 (T)4 * (C)3 * (V)4	Treat by maintaining an office of OEM. Maintenance landscaping, erosion control, jersey barriers and other practices.
Funding Uncertainty (positive and negative)	There is a risk of funding changes leading to increased/reduced investment that causes improved/diminished asset management outcomes.	38 (T)4 * (C)2.4 * (V)4	Tolerate/take advantage of—manage on per event basis.
Geohazards	There is a risk of geotechnical failure that causes mobility and safety impacts as well as increased asset management cost.	33 (T)5 * (C)3.3 * (V)2	Treat by implementing the geohazards management program and robust geohazards-management plan.
Cost Uncertainty	There is a risk that price escalation occurs, leading to unsustainable costs and thereby limiting the ability to deliver organizational objectives.	15 (T)3 * (C)1.65 * (V)3	Treat by bid process (e.g., bid rejection), re-scoping projects, price hedging, and by hedging materials; then tolerate.
Fire	There is a risk that fire occurs, leading to asset/route damage that causes mobility and safety impacts as well as increased asset management cost.	14 (T)4 * (C)1.2 * (V)3	Tolerate in the case of wildfires; and treat by tunnel fire-suppression systems and bridge-design standards, etc. Use tools and processes developed under the resilience program to identify high risk assets and corridors for focused analysis.

*Risk Score = Threat Likelihood (T) * Total Consequence and Consideration Score (C) * Vulnerability (V)

Threat/Opportunity	Risk Statement	Risk Score*	Risk Management Strategy
Missing Infrastructure Targets for National Performance Measures	There is a risk that CDOT is not able to meet PM2 condition minimum requirements, leading to restricted funding that limits the agency's ability to meet its objectives.	14 (T)3 * (C)2.4 * (V)2	Treat by implementing formal asset management program.
Snow (Avalanche)	There is a risk of avalanche occurring that causes mobility and safety impacts as well as increased asset management cost.	11 (T)4 * (C)2.7 * (V)1	Treat by maintaining a Winter Operations Program. Use tools and processes developed under the resilience program to identify high risk assets and corridors for focused analysis.
Cybersecurity	There is a risk that a cyber-attack occurs, leading to a reduction in CDOT ability/ effectiveness that results in reduced mobility and safety outcomes.	9 (T)5 * (C)1.8 * (V)1	Transfer to Governor's Office of Information Technology. Treat by maintaining firewalls; virus protection software; training employees on cybersecurity.
Staffing: Attrition	There is a risk that CDOT suffers from a shrinking workforce, leading to loss of institutional knowledge that reduces efficiency and effectiveness.	4 (T)4 * (C)1.1 * (V)1	Treat by documenting policies and procedures.

*Risk Score = Threat Likelihood (T) * Total Consequence and Consideration Score (C) * Vulnerability (V)

6.6 PROGRAM-LEVEL ASSET CLASS RISKS

In addition to the agency-wide risk register, each asset class is responsible for maintaining and monitoring risks in their asset class-specific risk register. Asset class owners identify and analyze risks as part of CDOT's regular update to the register.

The TAM Working Group works with the asset class owners to ensure the risk register is updated and provides input to the risk-management approach. Further, the TAM Working Group compiles the risks from each asset class. Where applicable, risks specific to asset classes may roll-up to the enterprise-level risk register. Each asset class plan in the Appendix includes the top three to five risks for each class, including responses to the risks and control measures in place to monitor the risks. **Tables 13** and **14** includes the top risks for bridge and pavement assets, respectively. Refer to the Asset Plan Appendix to review the top risks for the other 10 asset classes.

6.6.1 TOP RISKS TO PAVEMENT

Table 13 identifies the top risks to CDOT's pavement assets.

Table 13 *Top Risks for Pavement Assets*

Threat Number	Threat Title	Risk Statement	Risk Score	Risk Management Response
1	Construction Cost Escalation	There is a risk that construction cost variation occurs, leading to a reduced ability to deliver projects, which prevents achieving desired outcomes.	78 (T)4 * (C)3.9 * (V)5	Tolerate—Advance future-year funding, reduce planned treatments, deliver fewer projects, eliminate projects.
2	Pavement Forecasting Misalignment	There is a risk that a misalignment of the current pavement management model leads to incorrect forecasting of outcomes that causes reported NPM performance goals not to be met.	62 (T)4 * (C)3.9 * (V)4	Treat—Assessing misalignments, reviewing 1/10-mile NPM data, sharing focus areas with Regions, using funding for specific, focused projects.
3	Severe Weather—Fire	There is a risk that fire occurs as a result of severe weather, leading to local pavement damage (such as from post-fire debris flows) that causes diversion of funds and inability to meet performance goals.	58 (T)4 * (C)4.8 * (V)3	Treat—use tools and processes developed under the resilience program to identify high risk corridors for focused analysis and strategy development.
4	Severe Weather—Flood	There is a risk that flooding occurs as a result of severe weather, leading to pavement damage that causes diversion of funds and inability to meet performance goals.	45 (T)2 * (C)5.6 * (V)4	Treat—use tools and processes developed under the resilience program to identify high risk corridors for focused analysis. Develop reasonable alternative strategies when planned treatments are identified and prioritized.

6.6.2 TOP RISKS TO BRIDGES

Table 14 identifies the top risks to CDOT's bridge assets.

Table 14 *Top Risks for Bridge Assets*

Threat Number	Threat Title	Risk Statement	Risk Score	Risk Management Response
1	Bridge Strike	There is a risk that bridges are hit by vehicles, leading to repairs/closures that cause mobility/safety impacts.	60 (T)5 * (C)4 * (V)3	Treat—Replace or raise low bridges, lower grade.
2	Essential Repairs	There is a risk that essential unplanned repairs will be required, leading to reduced funding for other projects, which reduces the ability to meet performance goals.	48 (T)5 * (C)3.2 * (V)3	Treat— Use tools and processes developed under the resilience program to prioritize investments. Maintain a contingency fund for these repairs when required.
3	Inadequate Funding	There is a risk that inadequate funding occurs, leading to limited ability to preserve good bridges, which could cause the percentage of deck area in good condition to continue to decline.	44 (T)5 * (C)2.2 * (V)4	Tolerate—Continue to prioritize investment based on asset management principles.
4	Severe Weather—Flood	There is a risk that flooding occurs as a result of severe weather, leading to bridge damage that causes diversion of funds and inability to meet performance goals.	22 (T)2 * (C)5.4 * (V)2	Treat—use tools and processes developed under the resilience program to identify high risk corridors for focused analysis. Develop reasonable alternative strategies when planned treatments are identified and prioritized.

6.7 RISK AND RESILIENCE AS PART OF LIFE-CYCLE PLANNING AND LIFE-CYCLE COST ANALYSIS

CDOT asset managers currently develop their annual treatment lists based primarily on condition needs. To integrate risk more formally into decision making, the Department is refining processes and tools to incorporate risk management and resilience considerations into asset-management treatment selection and prioritization processes.

CDOT has undertaken a broad range of risk initiatives to understand and respond to risk. These can be viewed in detail on the CDOT website[6]. **Table 15** summarizes the range of CDOT's risk-management initiatives.

Table 15 *CDOT's Risk-Management Levels, Responsible Parties, and Risk Management Initiatives*

Level	Responsibility	CDOT Risk Management Initiatives
Enterprise	Senior Executives, policy makers	**Enterprise Risk Register (Enterprise-wide, Strategic, Corporate Risks)—**Documented list of risks that affect the mission, vision, and overall results of the asset management program. **Climate Change Impacts to CDOT—**CDOT is regularly assessing various impacts to its network based on climate change and extreme weather conditions, including its recent study, "Changing Climate and Extreme Weather Impacts on Geohazards in Colorado," conducted in 2021.
Program	Program Managers	**Enterprise Risk Register (Programmatic, Business Line Risks)—**Documented list of risks that affect CDOT's ability to deliver projects and meet targets within a program (but not related to a specific project). **Changing Climate and Extreme Weather Impacts on Geohazards in Colorado—**An assessment of how extreme weather and climate change may affect geohazard impacts through changes to their frequency and magnitude. **Asset Class-Specific Risk Register—**Documented list of risks that specifically affect one of CDOT's 12 asset classes. **4 R Framework for Identifying and Evaluating Resiliency in Transportation System Assets and Organizations—**Details the "4 R Principle" framework used to evaluate resiliency in transportation systems. The document provides examples of both a resilient organization and asset.

6 https://www.codot.gov/programs/planning/cdot-resilience-program

Level	Responsibility	CDOT Risk Management Initiatives
Project	Project Managers	**Colorado Department of Transportation Risk and Resilience Analysis Procedure—**A Manual for Calculating Risk to CDOT Assets from Flooding, Rockfall, and Fire Debris Flow (Pilot)—procedure documenting CDOT's approach to managing risk and resiliency to a specific highway asset from specific threats (developed based on Risk and Resilience I-70 Pilot). **Project Prioritization Score Sheet—**A Microsoft Excel tool that allows users to prioritize projects based on the level of risk mitigation addressed by each project. **CDOT Project Risk Assessment Tool—**A Microsoft Excel tool that describes how risk management will be structured and performed on CDOT projects; it follows the common risk-management approach and a standard risk register format, tailored to CDOT. **Region Engineers' Project Risk Management—**In project delivery CDOT utilizes a Project Risk assessment tool that provides a process and record for risk identification, analysis, response strategy definition, monitoring and control.
Activity	Activity Managers, staff	**CDOT's Damaged-Asset Database—**A database containing past damaged assets, which can be updated as additional assets sustain damage in emergency events. **Asset Criticality Model for System Resilience—**A process for determining asset criticality (impact to CDOT if an asset were to fail). **Asset Resiliency Mapping Application—**A GIS mapping tool that allows users to assess risk as it relates to environmental risk factors, including drought severity and wildfire risk, as well as asset conditions like highway Drivability Life, and social vulnerability documented by Disproportionately Impacted Community Census Block Groups. **Risk and Resiliency Tool—**A Microsoft Excel tool that allows users to calculate the total risk for an asset by inputting pre-mitigation data on each of the six criticality factors and performing a benefit-cost analysis on mitigation tactics.

6.8 ASSETS REPEATEDLY DAMAGED BY EMERGENCY EVENTS

Federal regulations require state DOTs to conduct periodic evaluations of facilities that have repeatedly required repair and reconstruction due to emergency events (23 CFR 667). To meet these requirements, CDOT maintains a database listing past damaged assets, and is developing processes to update the database as additional assets sustain damage in emergency events. The Department has also asked MPOs for data on locally owned damaged assets.

6.8.1 IDENTIFYING AND TRACKING TWICE-DAMAGED ASSETS AT CDOT

CDOT's process for identifying and tracking twice-damaged pavement and bridge assets involves the following activities:

- Review a list of pavement segments falling within the geographic boundaries of each emergency event.
- Review a list of any bridges within the geographic boundaries of each emergency event.
- Review bridge and pavement projects that may show relevant repair work in the geographic boundaries of the emergency events.
- Compare the above information to a list of projects funded by emergency response dollars.

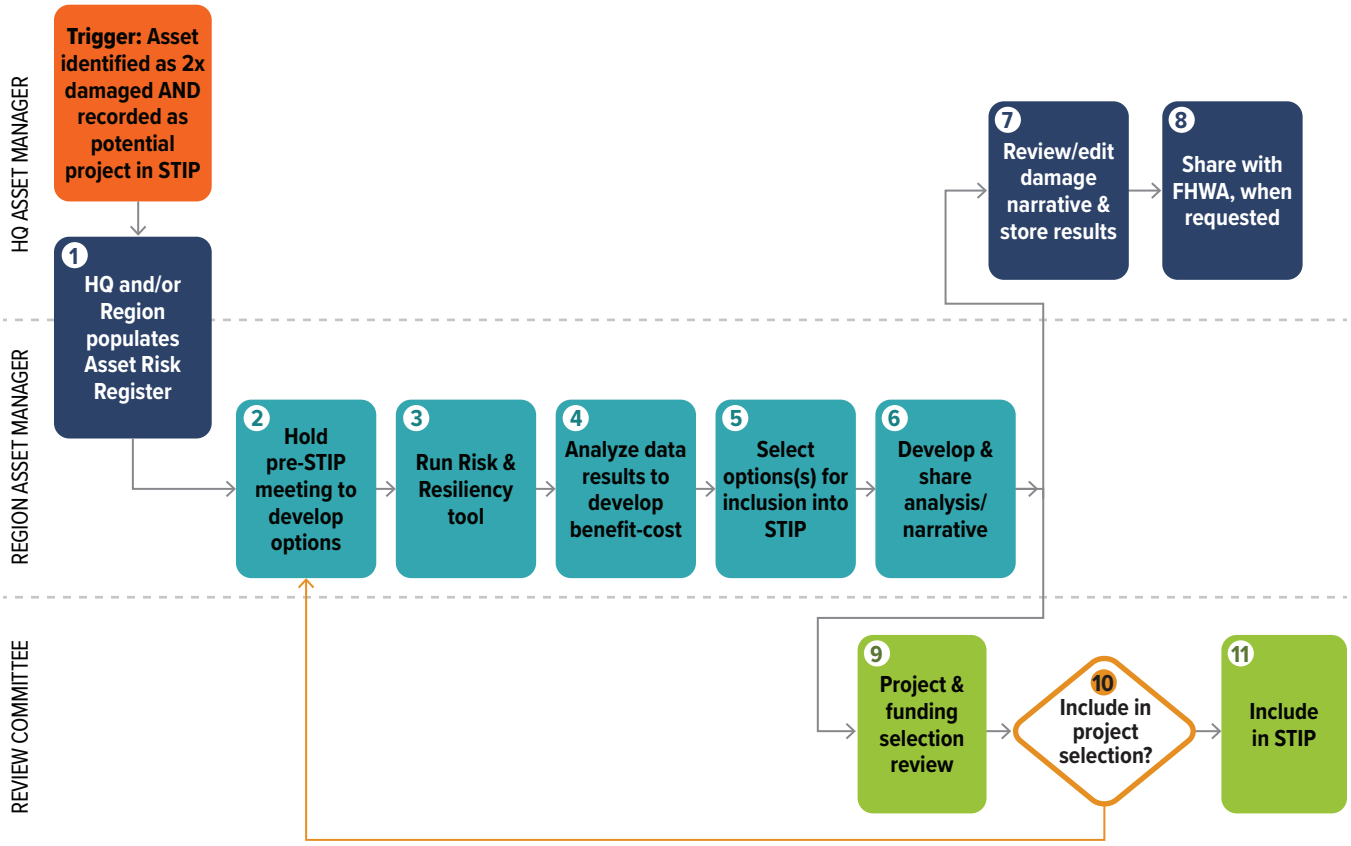
Based on this analysis, CDOT currently has identified two twice-damaged assets, both in the same location (see section 6.8.3). CDOT is working to identify corridors where other such incidents have occurred. Although there are few twice-damaged assets, the process of tracking events and developing analysis to identify areas of improvement and inform new projects has been established.

Going forward, CDOT expects this database will play a key role in new processes to determine whether actions to improve resiliency should be included when assets are due for maintenance, rehabilitation, or other treatments.

6.8.2 ASSESSING AND MITIGATING TWICE-DAMAGED ASSETS AT CDOT

As part of the resiliency program, CDOT plans to use data from past natural hazard events and predictive data from those same risks on the system to improve asset-management decisions. The process is being integrated into existing procedures and will allow CDOT to take a proactive approach to meet 23 CFR 667 requirements. Additionally, when resilience is built into a twice damaged asset, CDOT can remove that asset from future Part 667 reporting requirements. The process integrates into the Department-wide STIP planning process. A draft process map with step-by-step guidance for how CDOT assesses and mitigates twice-damaged assets are presented in **Figure 29**.

Figure 29 *DRAFT Process Flow for Assessing and Mitigating Twice-Damaged Assets*



		SUPPORTING INFORMATION
1	The HQ Asset Manager or Region Asset Manager will access the risk register and identify any new entries. Then document all newly identified twice damaged assets.	Asset risk register
2	The Region Asset Manager will form a team and hold a pre-STIP meeting to fill-out CDOT form 1048 to develop resilient options and run the resilience cost worksheet. The outputs from this meeting will be used to identify and gather data needed to run the risk and resilience tool (RnR).	Form 1048
3	The Region Team will run the RnR tool* for each option to create conceptual cost estimates.	RnR tool
4	The Region Team will analyze the risk reduction results from the risk & resilience tool to establish a benefit-cost of the proposed mitigation.	RnR results
5	The Region Team will select one or more options for developing the initial cost estimate for including this project and resilient options into the STIP.	Cost Estimate
6	The Region Team will develop a narrative to report and share results with the HQ Asset Manager.	Narrative
7, 8	The HQ Asset Manager will receive the results of the twice-damaged asset analysis, review and edit the narrative as required and share the narrative with FHWA when required. They will then prepare for any risk and resilience Emergency Operations Center (EOC) or commission presentations.	Information from the Region
9, 10, 11	After these steps are completed the Region Planner will include this project in the STIP.	STIP

* https://www.codot.gov/programs/planning/assets/risk-and-resiliency/risk-and-resiliency-tool_2022-01-20-1.xlsm

6.8.3 TWICE-DAMAGED ASSETS CASE STUDY: INTERSTATE 70 IN GLENWOOD CANYON

CDOT in 2020 and 2021 undertook a project to test and refine the process for assessing and mitigating twice-damaged assets.

Interstate 70A in Colorado, near milepost 124, has been the site of damaging rockfall events in 2016, 2010, and 2004. The 2004 and 2010 events both occurred at mile post 124.9, and both damaged the same bridge and retaining wall. The rockfall hazard at the site is above the westbound lanes but affects both directions of the Interstate, impacting geohazard, pavement, and bridge assets. CDOT performed an evaluation of the site, including the assets impacted.

The evaluation included an assessment of the threat likelihoods and three mitigation options to counter future rockfall events.

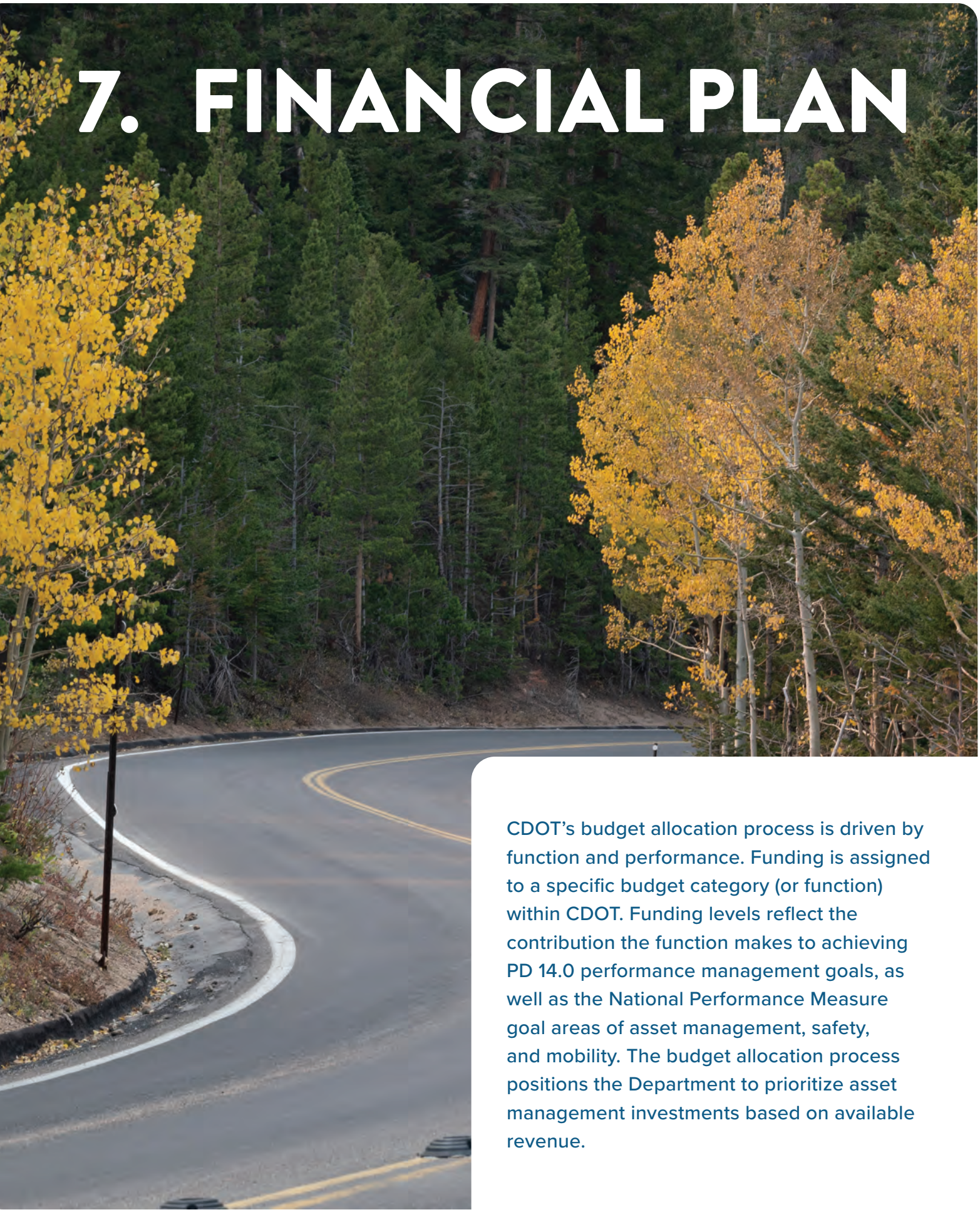
Following CDOT's Risk and Resilience Analysis Procedure, CDOT assessed each option, considering the likelihood of future threats, consequence of threats to both the owner (CDOT) and users, and vulnerability to future events. These options were then compared to a no-action scenario. **Table 16** outlines the outcomes of analysis of each of the three mitigation efforts. Annual risk mitigation benefits were primarily (97%+) made up of benefits to the road user.

Work crews evaluating one of the large boulders from the 2010 incident.

Table 16 *Analysis of Mitigation Options for I-70A Glenwood Canyon*

Option		Annual Risk Mitigation Benefit	Annual Cost (Installation + maintenance + replacement)	Benefit/Cost Ratio (annual return on each $ spent)	Expected Life
A	Rockfall Barrier A 105-foot 3,000 kJ rockfall barrier	$2.30 million	$19,000	121	20 years
B	Concrete Barrier A 270-foot concrete barrier fence extension	$1.35 million	$15,000	86	10 years
C	Attenuator A 175-foot attenuator	$1.59 million	$29,000	54	20 years

7. FINANCIAL PLAN



CDOT's budget allocation process is driven by function and performance. Funding is assigned to a specific budget category (or function) within CDOT. Funding levels reflect the contribution the function makes to achieving PD 14.0 performance management goals, as well as the National Performance Measure goal areas of asset management, safety, and mobility. The budget allocation process positions the Department to prioritize asset management investments based on available revenue.

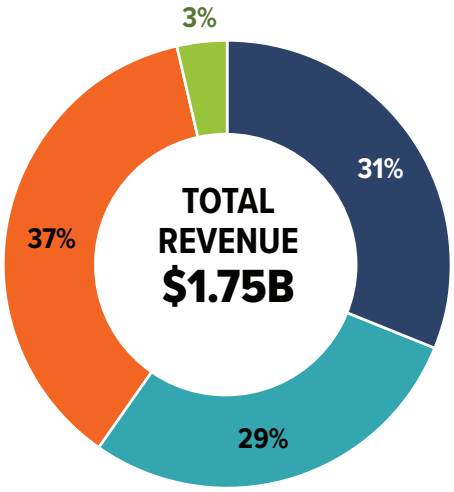
7.1 LINKING REVENUE TO ASSET MANAGEMENT OUTCOMES

The intention of this financial plan is to provide an understanding of revenue sources and how they support the achievement of CDOT's asset management performance targets, its asset management goal, as well as National Performance Measures. This is provided through consideration of:

1. **CDOT Revenue.** The sources of revenue for CDOT and how these may vary (e.g., how much is derived from motor fuel tax or federal funding).
2. **Revenue Allocation.** How CDOT divides up the revenue received and aligns this to achieving goals and objectives.
3. **TAM Budget Process.** The funds available for the TAM program and how that is divided between asset classes.

Also considered in this chapter is asset valuation as an indicator of whether investments are maintaining or improving value.

Figure 30 *Summary of CDOT Revenue FY 2021-22*



$546.8M Highway User Tax Fund (HUTF) Revenue
$0M General Fund
$500M SB 17-267 Lease-Purchase Agreements
$642.2M Federal Programs
$20M Aeronautics
$31.9M Miscellaneous
$7.7M State Multimodal Funding
$1.9M State Safety Education Funding
$200K State Infrastructure Bank
$500K Capital Construction Fund

Source: CDOT FY 2021–22 Final Budget Allocation Plan

7.2 CDOT REVENUE

CDOT's total revenue for FY 2021-22 is approximately $1.75 billion, as presented in **Figure 30**. Colorado's transportation system is financed by taxes and fees paid by users of the state and national transportation systems. CDOT receives revenue from five sources: state revenue, federal revenue, grants, miscellaneous sources (including sale of property, permits, and fines), and enterprise revenue.

The three primary revenue sources are as follows:

Highway Users Tax Fund (HUTF)	This fund comprises state-levied fuel taxes and fees associated with the operation of motor vehicles in the state. The State Treasurer distributes HUTF proceeds between CDOT, counties, and municipal governments, according to statutory formulas. CDOT HUTF revenue decreased substantially in 2020 and 2021 due to the impacts of the COVID19 pandemic. As shown in the table below, measures taken to reduce the spread of the virus resulted in a substantial drop in Vehicle Miles Traveled (VMT) throughout 2020 and early 2021. With the increased distribution of vaccines and corresponding rollback of restrictions (mid-2021 and 2022), the state's VMT has been returning to pre-pandemic levels.	» Motor Fuel Taxes—$299.3M » FASTER Revenue—$119.2M » FASTER Vehicle Fees and Vehicle Registration Fees—$106.9M » Miscellaneous—$21.4M
State Funding Programs	Senate Bill (SB) 17-267 directed the State Treasurer to execute lease-purchase agreements on existing state facilities to generate revenue for priority transportation projects. 25 percent of the funding is to be spent in rural areas and at least 10 percent is to be spent on transit projects. (FY 2019-2022). SB 260 includes implementation of several new transportation fees and General Fund transfers, creates or modifies four state enterprises, and adds new planning and environmental study requirements. (FY2023).	» Over the next five years state funding programs will contribute more than $2B in revenue to priority transportation projects.
Federal Programs	In addition to state sources of funding, CDOT relies on revenue from the federal government. Federal funding for highway and transit projects primarily comes from the federal Highway Trust Fund, which is funded with federal fuel taxes. In recent years, fuel taxes have been insufficient to fully fund the federal Highway Trust Fund, and it has been supplemented by transfers from the federal General Fund.	

On November 15, 2021, President Biden signed into law the Infrastructure Investment and Jobs Act Public Law 117-58. The measure, also known as the Bipartisan Infrastructure Law (BIL), provides $550 billion over fiscal years 2022-26 in new federal investment in infrastructure, including roads, bridges, mass transit, water infrastructure, resilience, energy, and broadband.

The analysis and numbers included in this TAMP include BIL. The processes described in this TAMP position CDOT to prioritize asset management investments based on the investment dollars available.

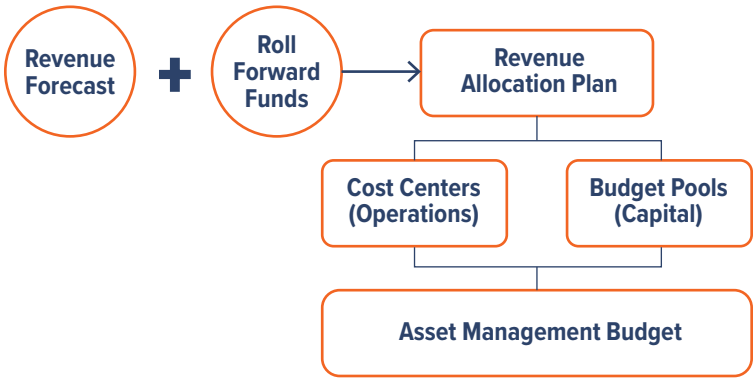
There are two state-owned enterprises that are critical to funding asset management at CDOT:

- **The Statewide Bridge and Tunnel Enterprise (BTE)** repairs, rehabilitates, and replaces bridges in "Poor" condition. BTE finances the design, repair, or reconstruction of designated bridges on the State Highway System using revenue generated from an annual bridge-safety surcharge collected from vehicle registrations, which generates roughly $125 million per year. SB 260 will increase this amount through a new Bridge and Tunnel Impact Fee anticipated to generate more than $500 million over a decade. Due to its Enterprise status, the BTE can issue its own revenue bonds based on the authority granted by Article X, Section 20 of the Colorado constitution to accelerate replacements or improvements of poor bridges. Tunnels were added to BTE's purview in 2021.
- **The Colorado Transportation Investment Office (CTIO)** leverages innovative ways of financing transportation, such as public-private partnerships, the operation of concession agreements, and fee-based projects.

7.3 REVENUE ALLOCATION

CDOT's Revenue Allocation Plan represents the amount of revenue the Department anticipates it will receive through the course of the fiscal year. The Revenue Allocation Plan is developed by allocating anticipated revenues for the upcoming fiscal year to budget programs. These programs are established to serve a specific departmental function—geohazard mitigation, for example. Each of the budget programs included in the Revenue Allocation Plan are composed of either cost centers or budget pools (see **Figure 31**). In general, cost centers represent the operating portion of the Department's budget, while budget pools represent the capital portion. In general, open projects from a prior fiscal year are paid for out of previously received revenues. The Revenue Allocation Plan represents new anticipated revenue that is available for operating expenses during the fiscal year, and for new capital projects.

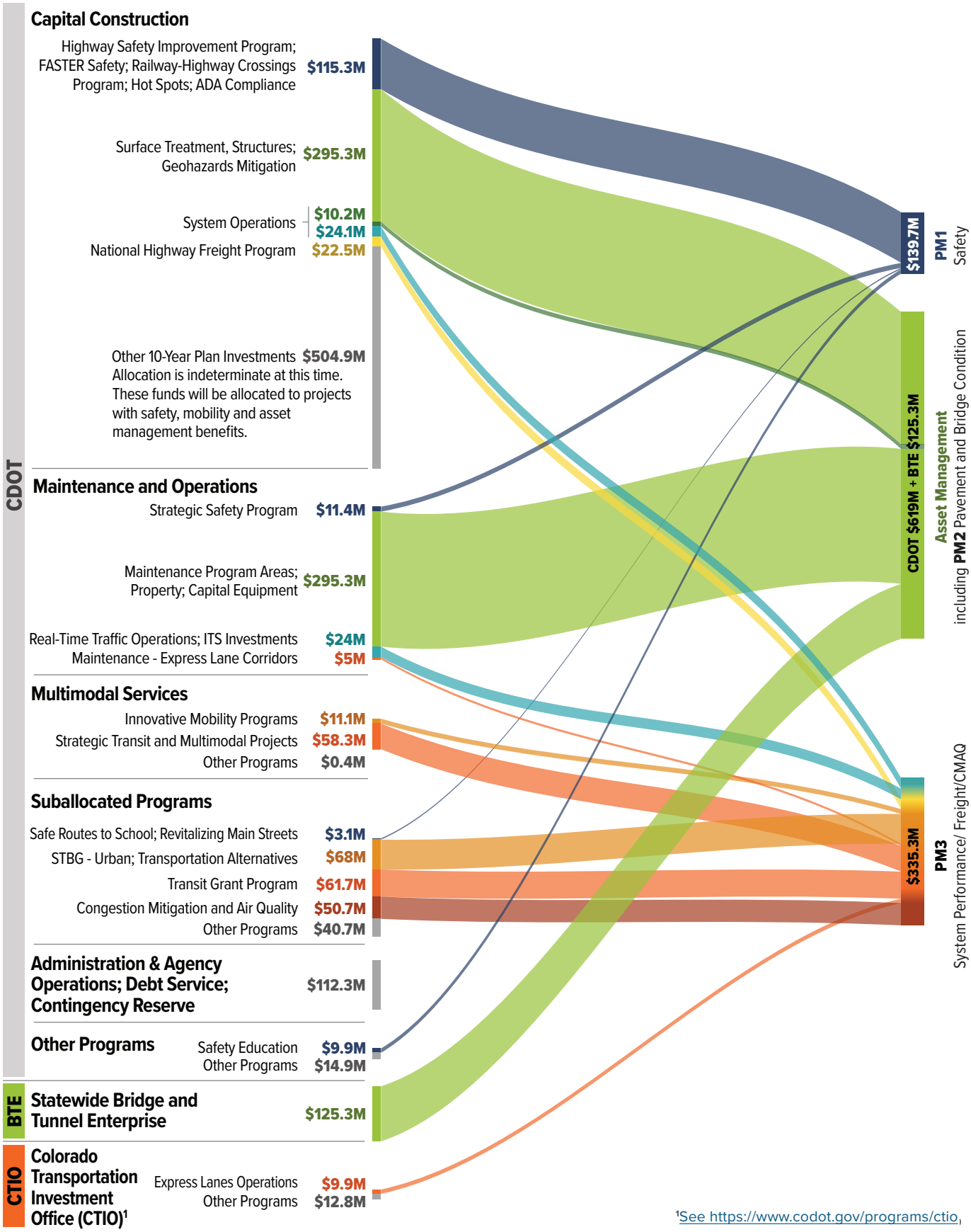
Figure 31 *CDOT Budget Allocation Process*



The budget for most of CDOT's core and support functions is allocated and directed by the Transportation Commission. When assigning budgets, CDOT considers performance management goals (defined in PD 14.0) and the National Performance Measure goal areas of condition (asset management), safety, and system performance (mobility). Although funding is assigned to a specific budget category (or function), it is also recognized for the contribution it makes to achieving state and federal performance goals. **Figure 32** provides an illustration of the connection of the FY 2021-22 budget categories to National Performance Measures.

Figure 32 *FY 2021-22 Budget Contributions to National Performance Measures*

CDOT investment decision-making considers the contributions made to achieving National Performance Measure targets for asset management, safety, and mobility.



[1]See https://www.codot.gov/programs/ctio

7.4 ASSET MANAGEMENT BUDGET ALLOCATION

The asset-management planning budget is split between the 12 asset classes using the process described in Section 5.1.3. **Figure 33** presents the split for FY 2021-22, assuming the total planning budget is $744 million, including the Statewide Bridge and Tunnel Enterprise.

7.5 INITIAL (NEW) CONSTRUCTION

CDOT's asset management program is dedicated to funding the existing transportation system—not expansion projects. The Department's investments in new pavement and bridge construction are funded outside of its asset-management program, through CDOT's 10-Year Plan. The Department in 2019 began the process to build this 10-year vision, meeting with Coloradans in every county. Thousands of comments and ideas became the basis for a prioritized list of transportation projects. The resulting *10-Year Vision* document identified transportation improvements across the state, ranging from long-deferred resurfacing projects to large and complex projects.

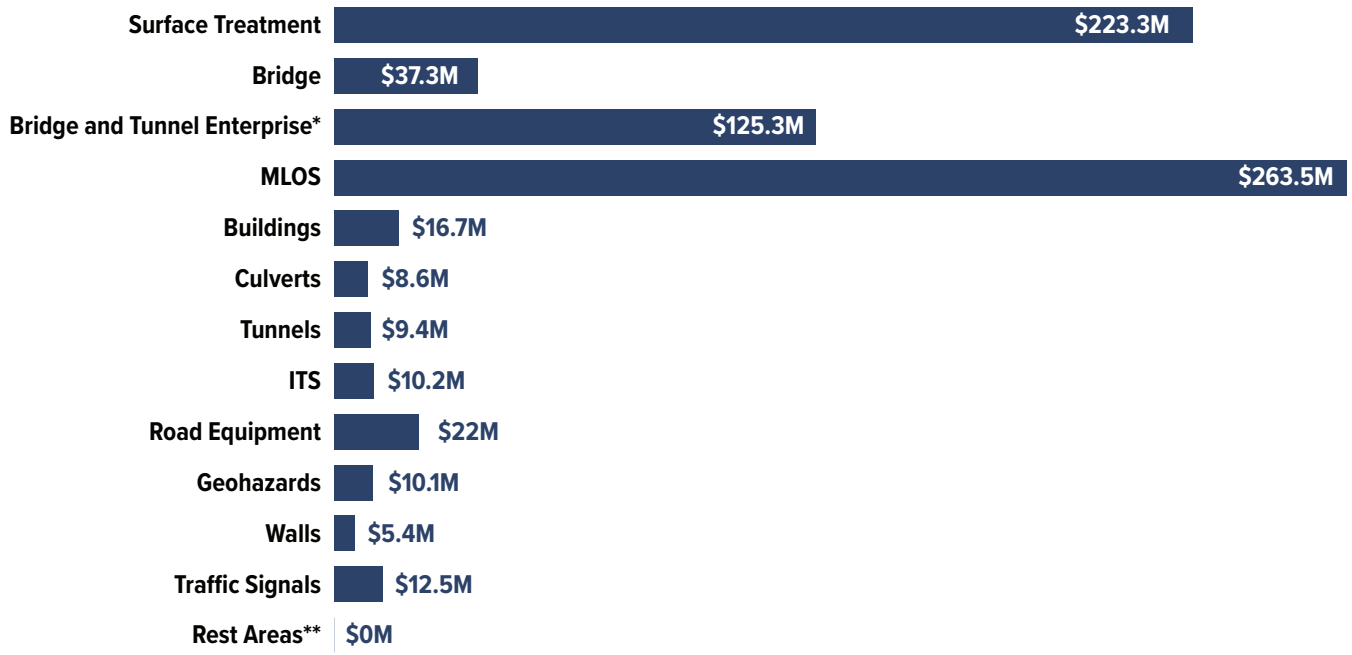
These projects can influence the performance outcomes that CDOT will achieve. Treatments to existing assets can enhance condition outcomes, and where these treatments are defined, they are incorporated in the AIMS model and reflected in predicted performance. Adding new assets creates additional asset management responsibility for CDOT. Although the new assets will not have a significant asset management impact in the timeframe of this TAMP, this ongoing commitment is considered during project planning.

Much of CDOT's "new" revenue sources—including funding from state Senate Bills 260 and 267, and certain new funds from the Infrastructure Investment and Jobs Act—is dedicated to supporting projects in the plan, including new pavement and bridges. CDOT defines new construction for pavement and bridges as follows:

- **Pavement:** New pavement construction includes capacity increases; pavement widening for capacity or safety reasons; and horizontal or vertical changes of pavement alignment.
- **Bridges:** New bridge construction means building a bridge where no bridge existed before, or new interchanges.

Figure 33 *Asset Management Funding Distribution by Asset, FY 2021-22*

The majority (almost 90 percent) of asset management funding goes to maintenance levels of service, pavements (surface treatment) and bridges (bridge and BTE).



* Based on BTE forecast. Note not all BTE revenue is available for projects due to existing debt service obligations and operational costs.
** Rest Areas is not funded from asset management until FY 2023.

To estimate the amount CDOT intends to spend on initial (new) construction for the next 10 years, CDOT's TAM program utilized the Department's 10-Year Strategic Project Pipeline. This document is maintained by the Multimodal Planning Branch and is mostly composed of projects that increase or enhance CDOT's system capacity in some way. The pipeline contains a mix of unfunded and funded projects. Due to the uncertain nature of the final years of pipeline funding, CDOT is unable to provide a forecast for new construction beyond FY24.

7.6 TAMP FINANCIAL PLAN—PAVEMENTS AND BRIDGES

CDOT develops a long-term financial plan for each asset class. This informs the AIMS model analysis and CDOT's budget-setting processes.

Table 17 provides the planned expenditure on pavements for the TAMP period of FY2022-31. The pavement financial plan includes anticipated funding for the Surface Treatment Program (pavement), the Maintenance Levels of Service program area for pavement, and initial construction. Planning budgets for the pavement program have been set through FY2024-25. Most estimated budgets are held at FY2024-25 levels for subsequent years in the AIMS analysis and table below. Maintenance Levels of Service budgets are actual budgets and for FY 25 and beyond these numbers are escalated at 3 percent per year.

Table 17 *Financial Plan for Pavement Assets (in Millions)*

	FY 22	FY 23	FY 24	FY 25	FY 26	FY 27	FY 28	FY 29	FY 30	FY 31
Surface Treatment	$223.3	$224.6	$225.6	$229	$229	$229	$229	$229	$229	$229
Maintenance Levels of Service	$40.4	$41.6	$40.7	$41.9	$43.2	$44.5	$45.8	$47.2	$48.6	$50.1
Initial Construction	$118.7	$118.7	$118.7	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total	$382.4	$384.9	$385	$270.9	$272.2	$273.5	$274.8	$276.2	$277.6	$279.1

Bridge financial plan numbers are estimated using the same approach as for pavements and presented in **Table 18**. The bridge financial plan includes anticipated funding for Staff Bridge (bridge program), Maintenance Levels of Service, Bridge and Tunnel Enterprise, and initial construction.

Table 18 *Financial Plan for Bridge Assets (in Millions)*

	FY 22	FY 23	FY 24	FY 25	FY 26	FY 27	FY 28	FY 29	FY 30	FY 31
Staff Bridge	$37.3	$37.3	$38.3	$38.3	$38.3	$38.3	$38.3	$38.3	$38.3	$38.3
Maintenance Levels of Service	$5.4	$5.2	$5.0	$5.1	$5.3	$5.4	$5.6	$5.8	$5.9	$6.3
Bridge and Tunnel Enterprise	$97.77	$54.24	$86.17	$84.90	$117.12	$76.43	$116.25	$121.38	$124.07	$128.66
Initial Construction	$93.2	$93.2	$93.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total	$233.3	$189.94	$222.67	$128.30	$160.72	$120.13	$160.15	$165.48	$168.27	$173.26

7.7 ASSET VALUATION

Asset valuation is a useful metric in understanding how asset management is preserving value through time. To that end, CDOT has taken steps to estimate the value of the agency's NHS pavement and bridges. CDOT has adopted a data-driven methodology that accounts for asset depreciation over time, going beyond current replacement value or straight-line depreciation. CDOT primarily uses a condition-based approach to calculate the value of bridges and pavements. This approach starts with asset value at construction cost or replacement value and discounts it by how much an asset is below the optimal condition. The approach also compares the remaining life of the asset to its initial service life.

Bridges are the largest asset class at CDOT by valuation. The value of the agency's NHS bridges in 2022 is estimated to be $15.1 billion. Measured against a replacement value of $28.7 billion, 49 percent of the value remains. The valuation analysis for bridges also considers obsolescence. An obsolescence factor is calculated based on an obsolescence age of 75 years and a linear increase in obsolescence relative to that age. The obsolescence factor reduces the value of the asset as shown by the formula below. A bridge built 75 years ago will have its condition-based value reduced by 50 percent.

Pavement is the second largest asset class at CDOT. The value of the agency's NHS pavement in 2022 is estimated to be $10.7 billion. Measured against a replacement value of $14.4 billion, 74 percent of the value remains.

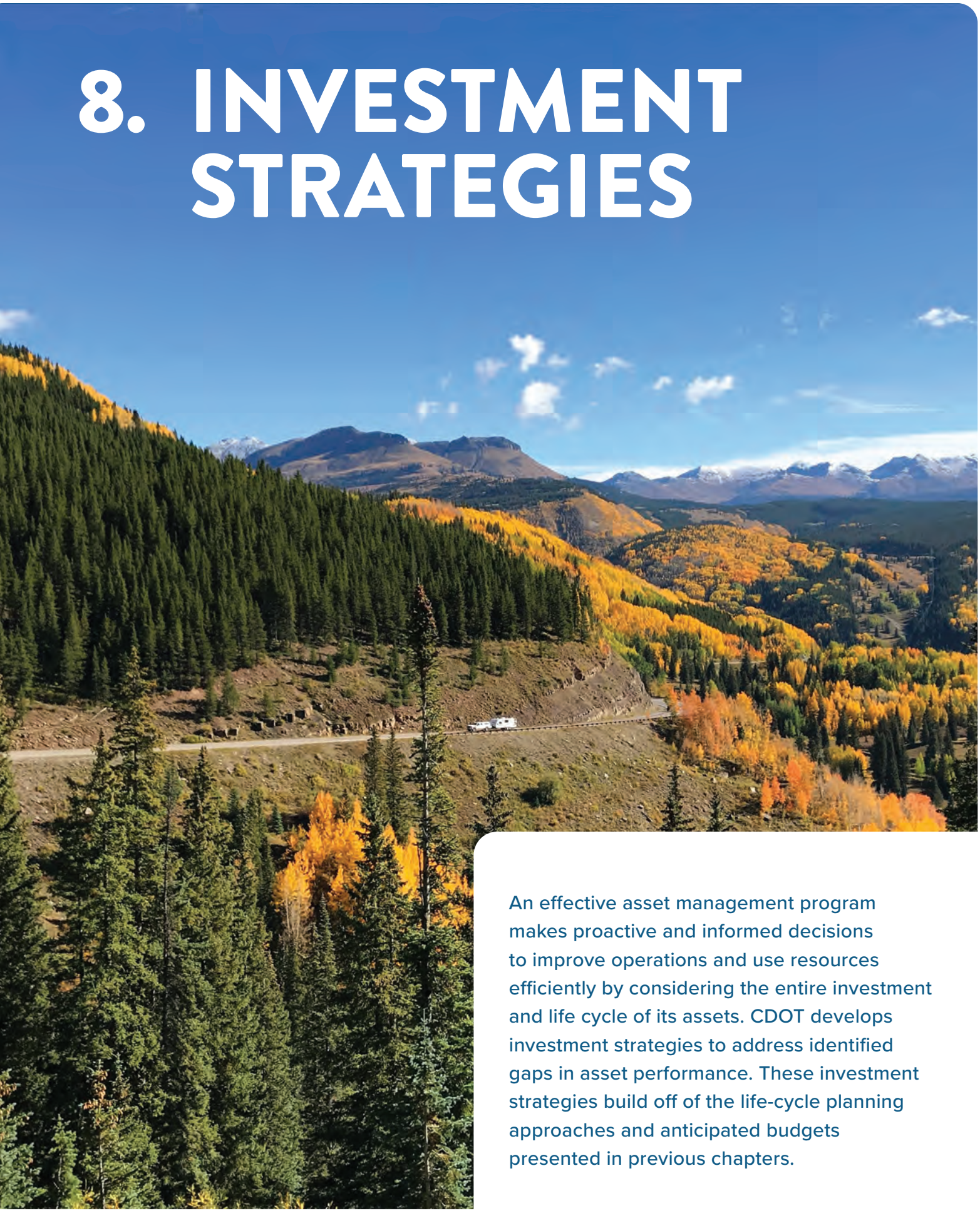
Figure 34 provides a summary of current values for CDOT assets. For assets other than pavements and bridges these numbers are discussed further in Appendix A.

Figure 34 *Current Asset Valuation*

Bridge current value equation, including obsolescence

$$\textit{Bridge current value} = \textit{Replacement Value} \times (\textit{Condition Rating}/9) \times \left(1-0.5 \times \frac{\textit{year today}-\textit{year built}}{75}\right)$$

8. INVESTMENT STRATEGIES



An effective asset management program makes proactive and informed decisions to improve operations and use resources efficiently by considering the entire investment and life cycle of its assets. CDOT develops investment strategies to address identified gaps in asset performance. These investment strategies build off of the life-cycle planning approaches and anticipated budgets presented in previous chapters.

8.1 PAVEMENT AND BRIDGE INVESTMENT STRATEGIES

CDOT uses its Asset Investment Management System (AIMS) model to assess various investment strategies and future outcomes. AIMS uses past performance data, deterioration curves for each asset, and treatment information (e.g., the cost and benefit of rehabilitating an asset) to predict an asset's future condition. Based on this, AIMS can also recommend asset treatments and optimize the budget allocation to create the best forecasted performance for the asset network.

The AIMS model determines an appropriate investment strategy by using asset treatments that generally align with the five FHWA specified work types:

1. **Maintenance—** A work type typically performed by the Maintenance Levels of Service (MLOS) asset class, which involves minor repairs on an asset.
2. **Preservation**—A work type designed to make an asset more durable to extend its life.
3. **Rehabilitation**—A work type that involves major repairs on an asset in poor condition.
4. **Reconstruction**—A work type in which the existing, original asset is torn down and replaced with a similar or identical structure.
5. **Initial Construction**—A work type where an entirely new asset is built where no asset existed before.

Pavement investment strategies are based on outputs from the AIMS model. The proposed investment strategies for pavement assets over the 10-year TAMP period are presented in **Table 19**.

Table 19 *Pavement Investment Strategy FY 2022–31 (in Millions)*

Work Type	FY 22	FY 23	FY 24	FY 25	FY 26	FY 27	FY 28	FY 29	FY 30	FY 31
Maintenance*	$40.4	$41.6	$40.7	$41.9	$43.2	$44.5	$45.8	$47.2	$48.6	$50.1
Preservation	$6.94	$28.99	$14.09	$7.30	$33.02	$27.44	$32.15	$24.51	$22.29	$22.29
Rehabilitation	$216.36	$195.62	$208.85	$221.70	$195.98	$201.56	$196.85	$204.49	$206.71	$206.71
Reconstruction	N/A	N/A	$2.67	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Initial Construction	$118.7	$118.7	$118.7	N/A	N/A	N/A	N/A	N/A	N/A	N/A
TOTAL	$382.4	$384.91	$385.01	$270.9	$272.2	$273.5	$274.8	$276.2	$277.6	$279.1

** Maintenance expenditure is from maintenance levels of service budget.*
FY30 and FY31 data for preservation and rehabilitation work types are averages.

Bridge investment strategies consider outputs from AIMS and historical expenditures to estimate the least life-cycle cost. The proposed investment strategies for bridge assets over the 10-year TAMP period are presented in **Table 20**. These numbers include Staff Bridge, Maintenance Levels of Service, initial construction, and Bridge and Tunnel Enterprise investments.

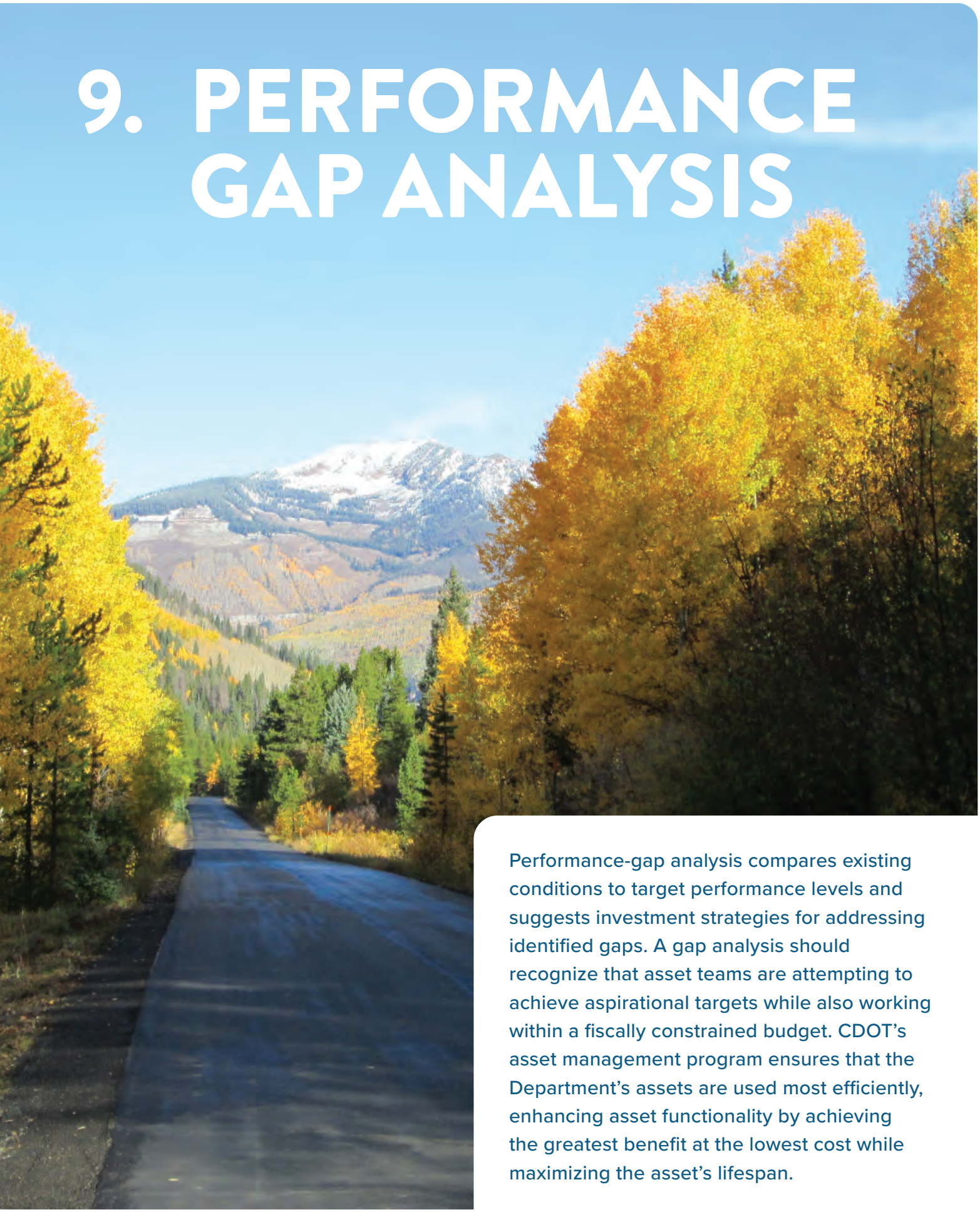
Table 20 *Bridge Investment Strategy, FY 2022–31 (in Millions)*

Work Type	FY 22	FY 23	FY 24	FY 25	FY 26	FY 27	FY 28	FY 29	FY 30	FY 31
Maintenance*	$5.4	$5.2	$5.0	$5.1	$5.3	$5.4	$5.6	$5.8	$5.9	$6.3
Preservation	$19.39	$22.15	$22.96	$16.76	$19.08	$20.92	$24.20	$38.15	$38.30	$31.88
Rehabilitation	$7.02	$15.15	$15.34	$21.54	$1.73	$0	$20.08	$0.15	$33.12	$32.39
Reconstruction	$108.65	$54.24	$86.17	$84.90	$134.61	$93.81	$110.27	$121.38	$90.95	$102.69
Initial Construction	$93.2	$93.2	$93.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
TOTAL	$233.3	$189.94	$222.67	$128.30	$160.72	$120.13	$160.15	$165.48	$168.27	$173.26

** Maintenance expenditure is from maintenance levels of service budget.*

The investment strategies shown for traditional asset management work types—maintenance, preservation, rehabilitation, and reconstruction—represent CDOT's base asset management program, including the maintenance levels of service program and the Bridge and Tunnel Enterprise. These funding levels are the majority of the Department's investments in these work types, but the totals do not include some investments from CDOT's 10-Year Plan. The Department has not included such investments, as it is still developing the ability to systematically disaggregate them from larger projects and consistently track delivery.

9. PERFORMANCE GAP ANALYSIS



Performance-gap analysis compares existing conditions to target performance levels and suggests investment strategies for addressing identified gaps. A gap analysis should recognize that asset teams are attempting to achieve aspirational targets while also working within a fiscally constrained budget. CDOT's asset management program ensures that the Department's assets are used most efficiently, enhancing asset functionality by achieving the greatest benefit at the lowest cost while maximizing the asset's lifespan.

9.1 STATE OF GOOD REPAIR

CDOT defines state of good repair based on the measures presented in PD 14.0. For pavements and bridges, these are summarized in **Table 21**. It is also necessary to consider performance gaps for pavements based on FHWA's National Performance Measures. Two- and four-year targets for the National Performance Measures are also shown below.

Table 21 *CDOT NHS State of Good Repair Definitions*

Asset Class	PD 14.0 Performance Measure	PD 14.0 Target (State Of Good Repair)	FHWA National Performance Measure Targets (NHS only)
Pavement	Percent with high or moderate Drivability Life (DL).	80% high or moderate DL	2-Year target* (2023) 45% Good, 4% Poor 4-Year target* (2025) 47% Good, 3.5% Poor
Bridge	Percent deck area on NHS and State Highway System in good condition, and percent deck area in poor condition.	40% or more in good condition 10% or less in poor condition	2-Year target (2023) 36% Good, 4% poor 4-Year target (2025) 36% Good, 4% Poor

**Interstate target.*

This TAMP considers several different parts of the highway network. These targets apply across each of these systems separately and together (e.g., the 80 percent high or moderate Drivability Life target for pavements applies to the Interstate, non-Interstate NHS, and the NHS as a whole).

9.2 PAVEMENT GAP ANALYSIS

As part of the annual budget-setting process, CDOT forecasts various funding options and expected outcomes using its AIMS asset model.

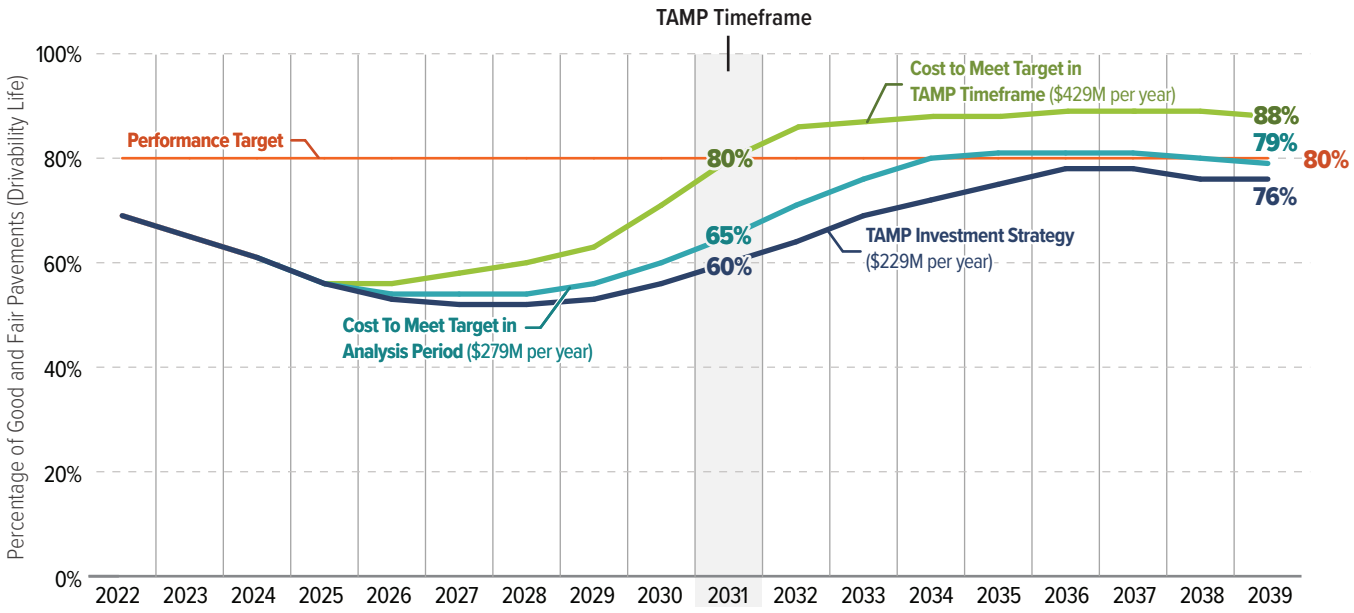
For pavements, planned projects are entered into AIMS by pavement segment. For the purposes of the TAMP, this was current as of November 2021.

Potential asset treatments (e.g., rehabilitations and replacements), including costs and condition benefits, are also supplied to AIMS. Adjustments to the treatment parameters (costs/benefits/triggers) are completed by CDOT on a periodic basis and updated in AIMS. Deterioration curves are used to predict future performance of each pavement segment. These deterioration curves are updated on an annual basis. The analysis is undertaken over a minimum period of 20 years.

Figure 35 presents the expected outcomes for both the proposed investment strategy and for an alternative scenario that enables the PD 14.0 (state of good repair) target to be met.

Figure 35 *Effect of Funding Levels on Pavement Condition of Colorado State Highway System*

Based on proposed investment levels, pavement condition is expected to fall until 2027 and then recover. Current funding will not achieve the performance target in the TAMP timeframe (2031). An additional $50M per year would be required to meet the performance target by 2034.



From 2022 through 2025, this analysis uses budgets that have already been set. Therefore, funding scenarios only begin to differ after 2025. The large dip occurring up to 2025 is caused by the large percentage of lane miles with a base year Drivability Life of five or less, which in the model are classified as "Low Drivability" life. Early on (up to 2025) in the analysis, the Drivability Life for these lane miles deteriorates from five down to zero. The model analysis projects the dip to continue for the first nine years.

Under CDOT's planned investments, pavement condition reaches 79 percent in 2036, short of the 80 percent target. To achieve the target over the analysis period would require an additional investment of $50 million per year. To reach the target within the TAMP timeframe (by 2031) would require a significant additional investment of $200 million per year from 2026-31. CDOT has also developed AIMS to be able to report FHWA National Performance Measure outcomes. **Figure 36** presents these results for the TAMP investment strategy.

For each portion of the highway system reported in **Figure 36**, there is a significant drop in pavements from good to fair condition over the TAMP period of 2022-2031. It is expected that this dip is similar in nature to the drop in Drivability Life shown in **Figure 35** and will be recovered over time. The model forecasts that the number of lane miles dropping to Poor is relatively low (and managed), so the proposed investment strategy will be to focus on preservation of Good and Fair segments.

9.3 BRIDGE GAP ANALYSIS

CDOT develops its bridge forecast by entering planned projects into the AIMS model. The model then begins recommending projects for the period that does not have planned projects, which is currently the period beyond 2025. **Figure 37** presents the expected outcomes for the proposed investment strategy. The modeled forecast uses bridge deterioration models developed in January 2022.

Analysis shows that a reduction in annual funding of $10 million would, over the long-term, cause CDOT to miss the PD 14.0 target of 90 percent of bridges being in good or fair condition. Such a reduction is purely illustrative and is not planned. Analysis also shows that to maintain the estimated 2022 condition level (96% of bridges in Good or Fair condition), an additional annual investment of $200 million will be required. An investment approach that maintains current condition would exceed the current performance target and is not proposed based on competing budget demands.

Figure 38 presents the expected outcomes for different systems based on the planned investment strategy.

This analysis shows that there are no performance gaps within the 2022-31 timeframe of the TAMP, but the long-term analysis illustrates that continued investment is required to continue to achieve performance outcomes. The cost to eliminate the backlog of poor bridges is approximately $2.2 billion.

9.4 NHS GAP ANALYSIS

In addition to identifying physical-condition gaps (see previous sections), FHWA requires state DOT asset-management plans to identify gaps in the effectiveness of the NHS in providing for the safe and efficient movement of people and goods.

To align CDOT's performance targets with its safety goals, the Department maintains a Strategic Transportation Safety Plan (STSP). The plan establishes a collaborative and shared mission for transportation safety in Colorado by identifying Colorado's key safety needs for guiding investment decisions toward strategies and countermeasures with the highest potential to save lives and prevent injuries. CDOT, the Colorado Department of Health and Environment (CDPHE), the Colorado State Patrol (CSP), and the Colorado Department of Revenue (CDOR) are the lead agencies that direct the development of the STSP, considering input from other key stakeholders.

9.5 CLOSING GAPS

CDOT may alter its existing strategy by adjusting treatments, condition targets and other factors to help close performance gaps. The Department also analyzes funding relative to targets at its annual budget-setting workshop for asset management and may adjust funding recommendations should analysis warrant it. Additionally, the Transportation Commission each year is briefed on performance versus targets in PD 14.0 and may adjust funding to address gaps. Finally, the Life-Cycle Planning and Investment Strategies sections of this plan describe high-level CDOT investment strategies and methods for closing performance gaps.

Figure 36 *FHWA National Performance Measure for Pavement—Projected Condition Outcomes*

NHS (Interstate and Non-Interstate) and State Highway System condition will stay relatively consistent until 2027. By 2031 the amount of good pavement will fall by approximately 20 percent when compared to pre-2028 levels.

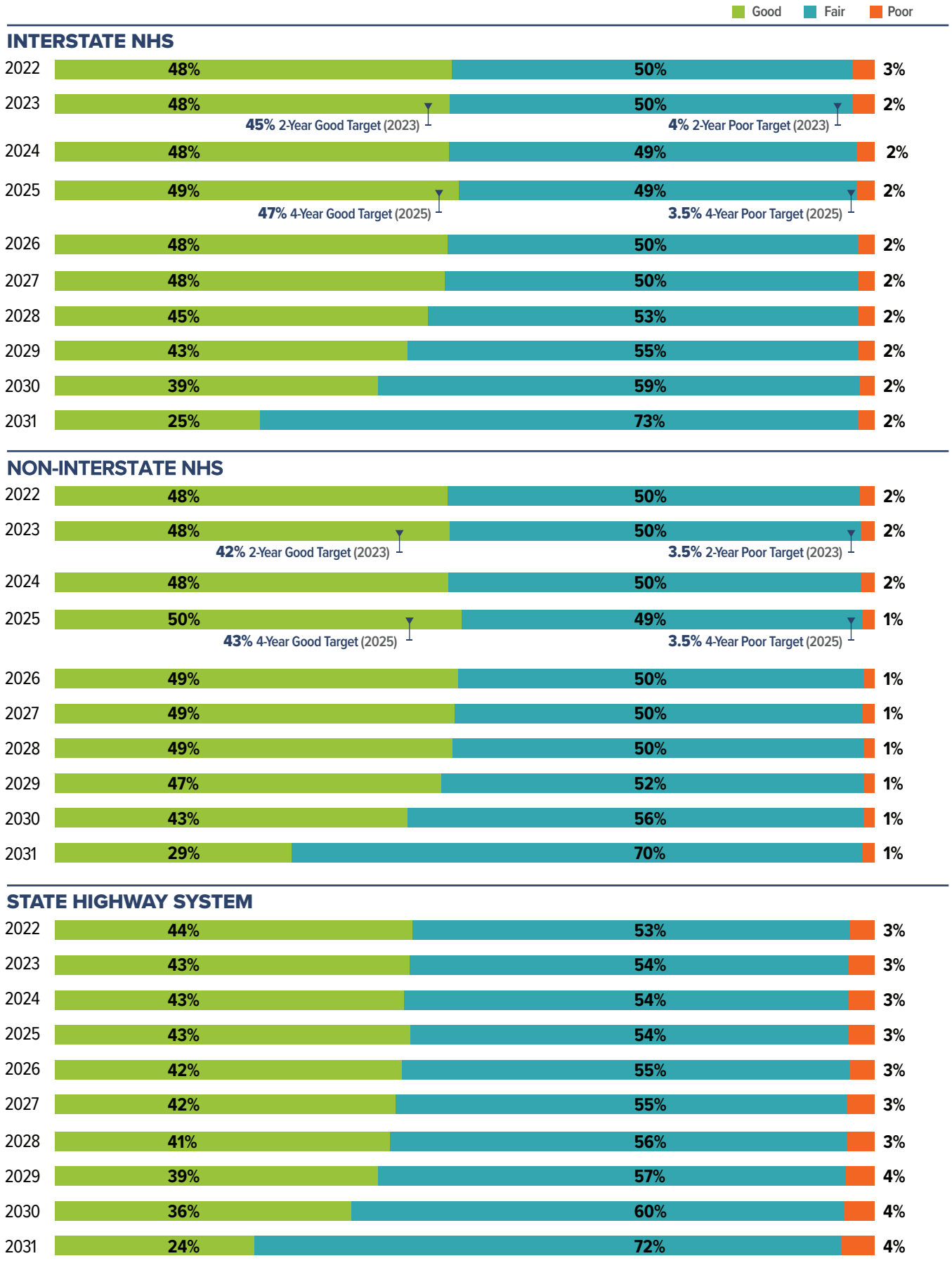


Figure 37 *Bridge Condition Forecast, State Highway System*

Based on proposed investment levels, bridge condition is expected to stay relatively consistent till 2032 and then begin to fall. Current funding will achieve the performance target.

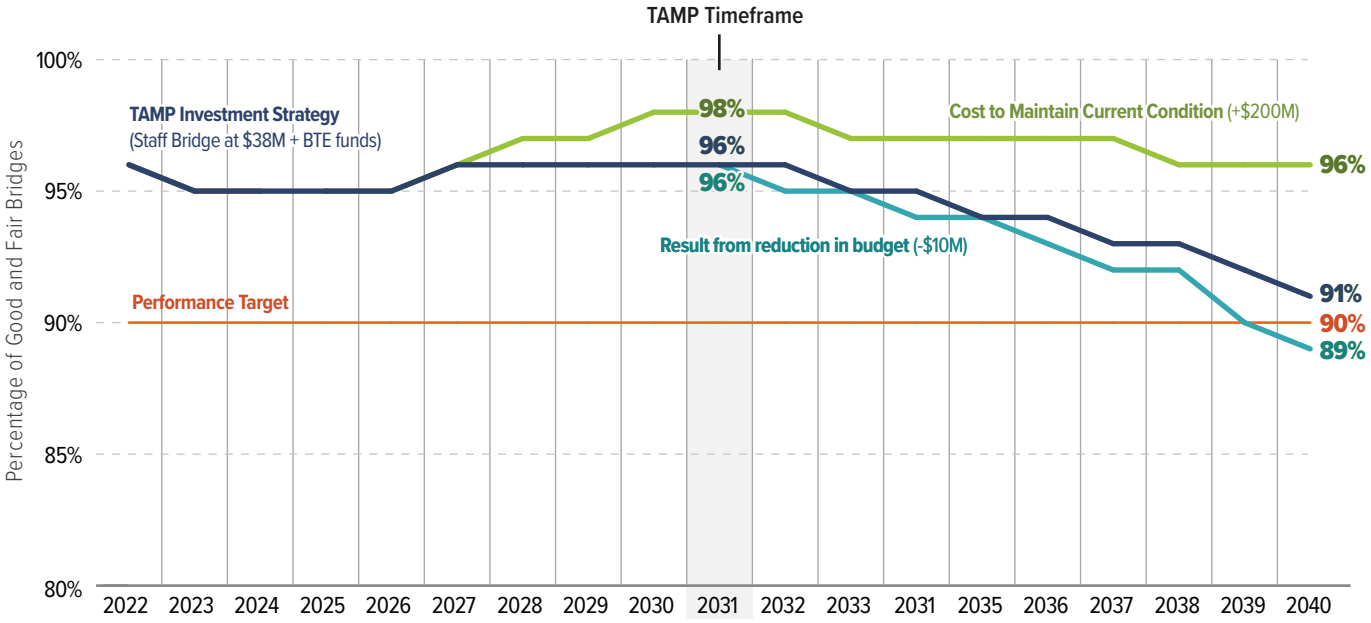
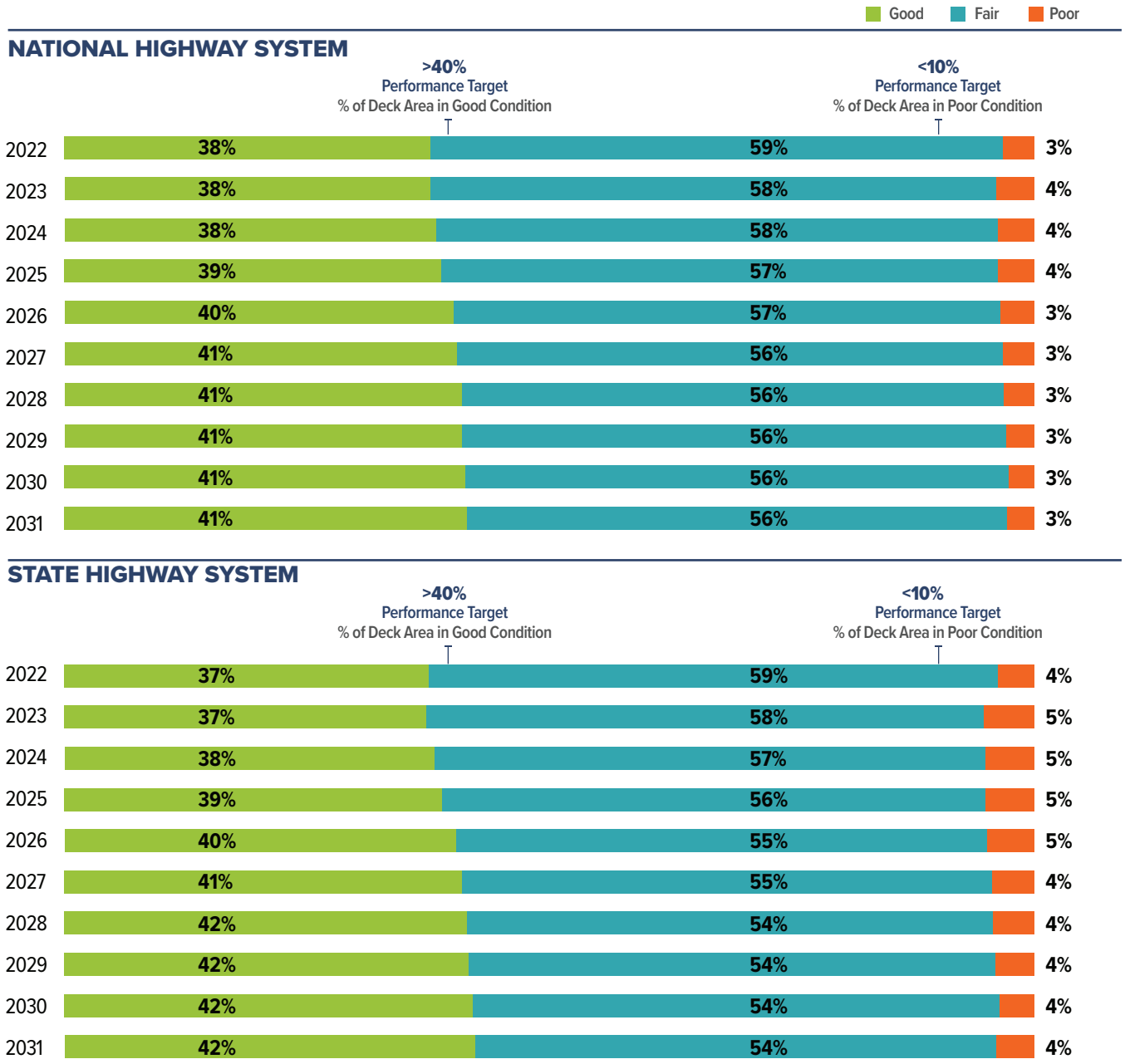


Figure 38 *Bridge Condition Forecasts by Highway Category*

The percentage of Good bridge deck is expected to increase in the next 10 years. The percentage of Poor bridge deck is expected to be maintained at current levels. Performance targets will be met over the next 10 years.

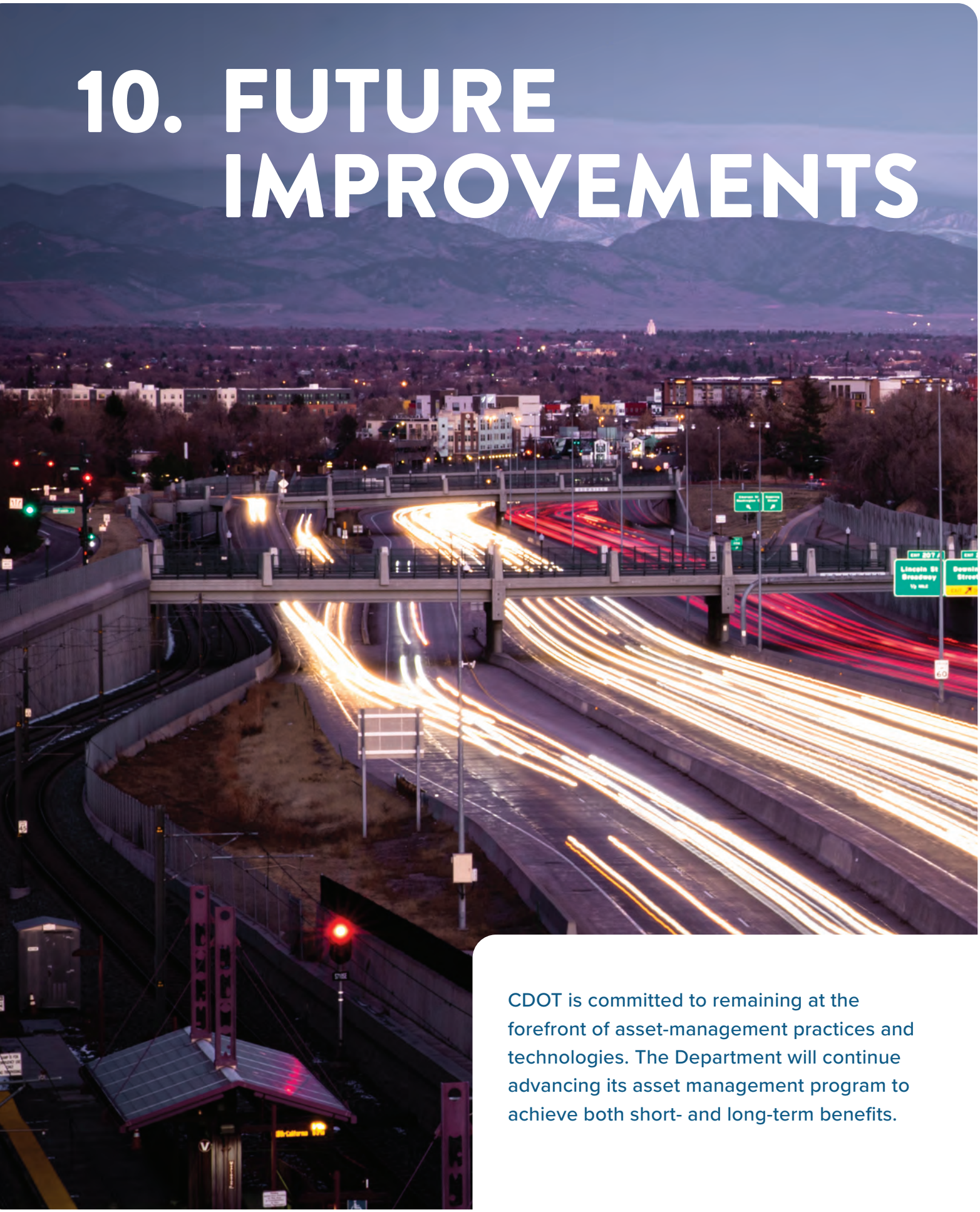


NOTES:

FHWA National Performance Measure Targets:
2-Year target (2023) 36% Good, 4% Poor
4-Year target (2025) 36% Good, 4% Poor

While the percentage of poor deck area on the NHS is expected to decline, challenges lie ahead in managing the aging population of structures. Specifically, the Department faces an extensive inventory of poor bridges in the Denver Metro area, and the large statewide inventory of fair structures will require high levels of consistent maintenance and investment to prevent them from falling into poor condition.

10. FUTURE IMPROVEMENTS



CDOT is committed to remaining at the forefront of asset-management practices and technologies. The Department will continue advancing its asset management program to achieve both short- and long-term benefits.

10.1 CONTINUOUS IMPROVEMENT

CDOT's asset-management program strives for continuous improvement. The next two sections describe anticipated improvements to the pavement and bridge asset classes, and are followed by improvements planned for CDOT's overarching asset-management program.

10.2 PAVEMENT PROGRAM IMPROVEMENTS

Intended improvements to the pavement asset class address people, processes, and technology.

PEOPLE

CDOT anticipates a continued need over the 10-year TAMP period to maintain and improve training for headquarters and Region staff in operating the AIMS models—both the existing Drivability Life model and the National Performance Measures model.

PROCESS

Process improvement is a key aspect of advancing asset programs. The pavement management team is currently part of a Joint Process Review with FHWA entitled "Improving How CDOT Manages Interstate Pavement Condition." The objective of this review, conducted as part of CDOT's Quality Improvement Council (QIC), is to identify and document opportunities for refining cross analysis of CDOT's Drivability Life metric/model and the National Performance Measure (NPM) for pavement. The review will identify possible solutions to bring Drivability Life and the NPM into closer alignment. CDOT anticipates implementing the recommendations over the next several years, provided funding and consultant support are available.

Another process improvement is encouraging Regions to consider incorporating more recycled materials into their surface-treatment projects when appropriate. The pavement management team is encouraging more of these materials through updates to the form it gives to Regions to develop annual treatment lists.

TECHNOLOGY AND ANALYSIS

Developing stronger forecasting and project-selection analyses through the AIMS model is an ongoing area of improvement. For example, the pavement team is implementing several improvements for the new fiscal year's model, such as:

- Transverse crack lengths will be used in the model instead of transverse crack counts. Transverse crack lengths will more accurately represent the extent of such cracking on CDOT's highways.
- The chip seal treatment has been revised so that more chip seals will be applied to CDOT's High and Moderate Drivability Life highways to maintain them in High and Moderate condition.
- Changes to the model will allow minor rehabilitations on more lower-volume roads that have significant distress.

10.3 BRIDGE PROGRAM IMPROVEMENTS

As with the pavement program, intended improvements to CDOT's bridge program address people, processes, and technology.

PEOPLE

CDOT anticipates a need over the 10-year TAMP period to train Staff Bridge and other staff to use its new System for Inspection and Management of Structural Assets (SIMSA) software, as well as to operate the AIMS model. SIMSA will provide easier access to CDOT's structure and inspection data for stakeholders such as MPOs, CDOT staff, and local-agency owners, while also streamlining the structure inspection and data-collection processes. Because the SIMSA platform is still under development, communicating the capabilities of the system to staff and other stakeholders will be an ongoing effort. It is expected that SIMSA development will be finalized in the next two to three years.

Separately, documentation is critical to ensuring knowledge transfer between staff, and CDOT has been making improvements to documentation of the AIMS model, including deterioration assumptions, individual model runs and their parameters, and more. These efforts will continue over the TAMP timeframe.

PROCESSES

The Staff Bridge unit and the Statewide Bridge and Tunnel Enterprise (BTE) are working to optimize life-cycle planning approaches. The Department intends to increase its efforts to research life-cycle treatments and their effects, including how treatments can increase resilience and address extreme weather events.

The Bridge and Tunnel Enterprise performs most of the bridge-replacement work in the state, and takes ownership of the CDOT bridges it addresses. The enterprise was formed in 2009, so most of its inventory has an average age of less than 10 years. Because the enterprise is Colorado's largest source of dedicated bridge funding, it has the opportunity to develop a fully funded plan to perform preventive maintenance treatments on its structures at the appropriate intervals. Implementing a comprehensive life-cycle plan that prioritizes asset management principles will maximize the return on investment for the enterprise's bridge replacement and rehabilitation projects by extending the service life of BTE-owned assets.

In another planned improvement, Staff Bridge has identified an opportunity to increase its coordination with the Department's long-range planning efforts. In doing so, it hopes to add value to projects and take advantage of economies of scale (e.g., shared costs of traffic control) by adding asset management treatments to projects that are not asset-management specific.

TECHNOLOGY AND ANALYSIS

Future process improvements will establish stronger forecasting capabilities and integrate more robust asset management practices into the Bridge program.

To that end, CDOT is collaborating with the University of Colorado Denver on developing the capability to forecast bridge deterioration through machine learning. The initial phase of this research has been completed and incorporated historical National Bridge Inventory, traffic, and weather data to forecast future bridge conditions. The next steps of this research will be to fine-tune the deterioration model and look at incorporating historical treatment data.

Separately, the SIMSA software will offer new technology and analysis capabilities that must be refined, including:

- Consolidating bridge data (e.g., condition, inventory) for easy access and use throughout the Department, including serving as a platform to upload and access "as-built" plans.

- Streamlining bridge inspection and inventory data collection and review for more accurate, up-to-date information.
- Integrating with CDOT's AIMS model so that data uploads (e.g., new condition and inventory data) to the model are easier than in the past.
- Making bridge inspection and inventory data accessible to local agencies, including counties, municipalities, and MPOs.

10.4 TAM PROGRAM: TARGETED IMPROVEMENTS

As with the pavement and bridge programs, CDOT's overarching Transportation Asset Management program focuses on continuous improvements and has identified future areas for enhancement. These areas are documented in **Figure 39** below. Improvements are categorized as short-, mid-, or long-term.

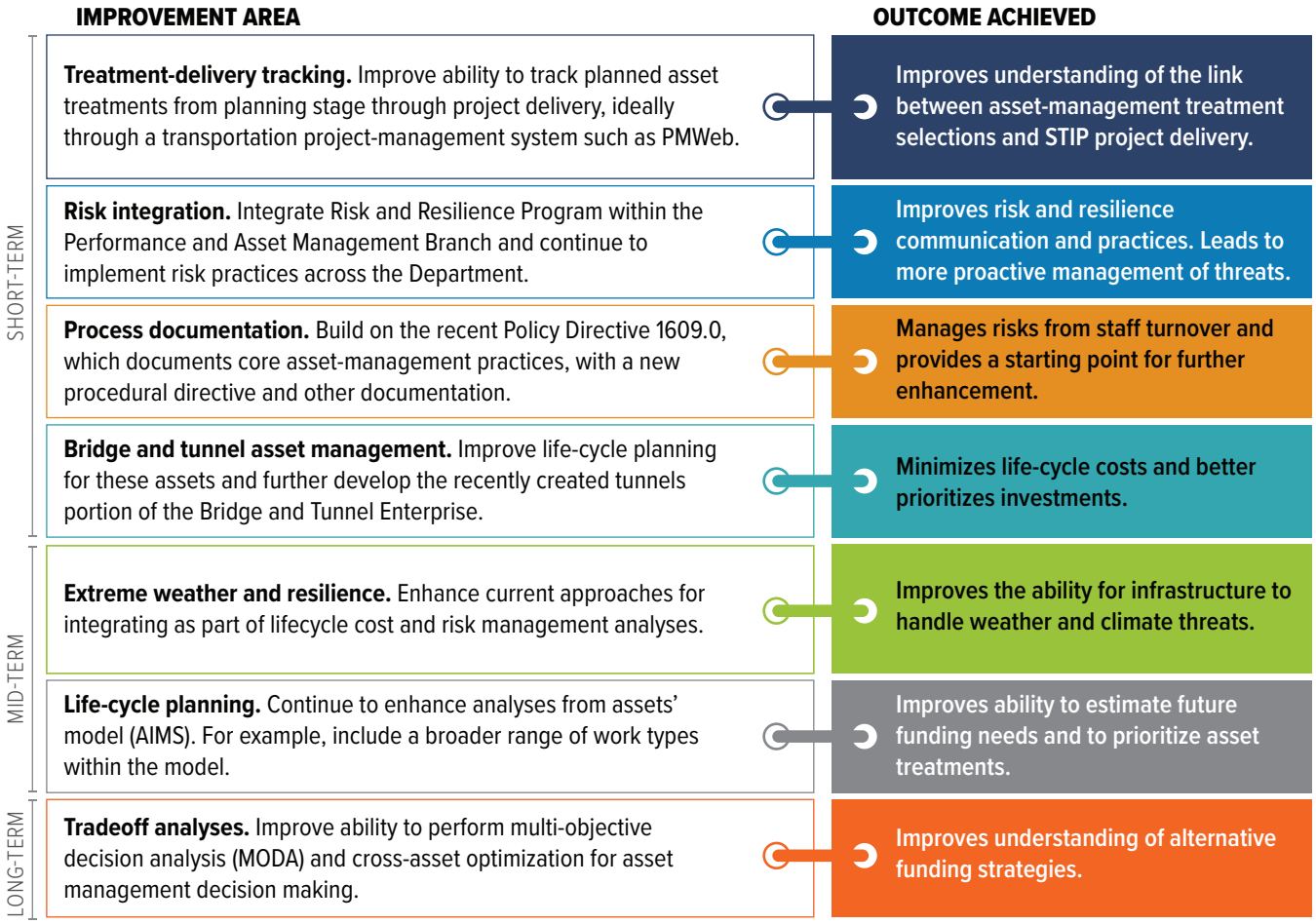
The items listed in this section will enable CDOT to enhance processes and further optimize asset investments. Continuous improvement will enable achievement of the Department's asset management performance goal of maintaining a high-quality transportation network by working to maintain a state of good repair for all assets and a highly traversable road network.

10.5 IMPLEMENTING THE TAMP

With careful planning and informed investment, new pavement can last for decades, and the service lives of bridges can stretch a century or longer. That means that the asset management decisions CDOT makes now are important not only for the traveling public of today, but tomorrow as well.

As with any plan, the success of this TAMP hinges on implementation. Delivering on the processes and investments outlined in this plan is critical to achieving the two- and four-year targets for National Performance Measures for pavement and bridges, as well as the longer-term asset forecasts contained herein. Successful implementation of this plan is an important step in establishing a legacy of sound transportation asset-management practices and a state of good repair for Colorado's highways for generations to come.

Figure 39 *Future Improvement Areas*



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Britton Stocks and Nathaniel Benton	Asset Management Modeling Analysts
Jennifer Thao	Asset Management Intern

RESILIENCY PROGRAM MANAGER

Lizzie Kemp Herrera

ASSET MANAGERS

Patrick Holinda	Statewide Bridge and Tunnel Enterprise
Craig Wieden and Laura Conroy	Pavement

ASSET MANAGERS (CONTINUED)

Michael Collins and Natasha Butler	Bridges
Howard Ray	Fleet
BJ Jacobs	Maintenance Levels of Service
Allie Axley	Intelligent Transportation Systems (ITS)
Hope Wright	Buildings
Natasha Butler	Culverts
Tyler Weldon	Tunnels
Bob Group and Nicole Oester	Geohazards
Natasha Butler	Walls
Nitin Deshpande	Traffic Signals
Hope Wright	Rest Areas

PERFORMANCE ANALYST

Jacob Kershner

PERFORMANCE DATA MANAGER

Darius Pakbaz

ACCOUNTING AND FINANCE

Eric Ehrbar	Pool Operations and Project Execution Manager
Katie Carlson	Budget and Policy Analyst
Joellen Meyer	Budget Analyst

ECONOMIST

Alejandra Garcia Acevedo

CONSULTANT SUPPORT

Gareth McKay	WSP
Aisha Anders	
Chris Senesi	
Rebecca Holzwarth	WSP
Alan Lubliner	WSP
Richard Boadi	WSP
Brad Allen	Applied Pavement Technology

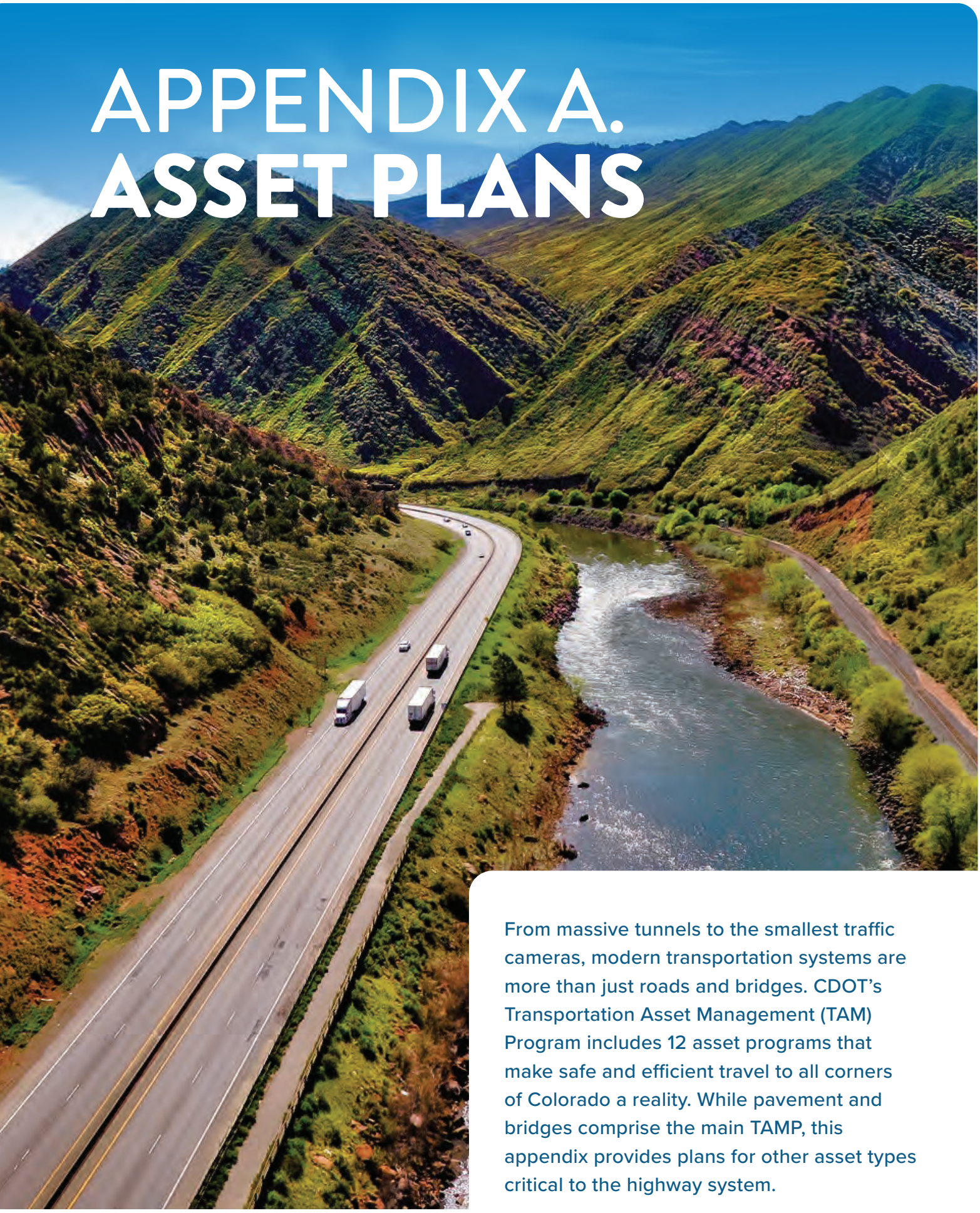
LIST OF ACRONYMS

AADT	Average Annual Daily Traffic
AASHTO	American Association of State Highway and Transportation Officials
ACR	Add/Change/Remove
ADA	Americans with Disabilities Act (federal)
AIMS	Asset Investment Management System
ARPA	American Rescue Plan Act (federal)
ATMS	Advanced Transportation Management System
ATSPM	Automated Traffic Signal Performance Measures
BIL	Bipartisan Infrastructure Law (federal, also see IIJA)
BrM	AASHTOWare's Bridge Management Database
BTE	Bridge and Tunnel Enterprise
C2C	Center-to-Center Communication
CAV	Connected and Automated Vehicle
CBE	Colorado Bridge Enterprise
CDOT	Colorado Department of Transportation
CDPHE	Colorado Department of Health and Environment
CDOR	Colorado Department of Revenue
CSP	Colorado State Patrol
CFR	Code of Federal Regulations
CMAQ	Congestion Mitigation and Air Quality Improvement
COTAMUG	Colorado Transportation Asset Management User Group
CRV	Current Replacement Value
CS	Condition State
CSP	Colorado State Patrol
CTIO	Colorado Transportation Investment Office
CTMC	Colorado Traffic Management Center
CTMS	Corridor Trip Monitoring System
DL	Drivability Life
DMO	Division of Maintenance and Operations
DOT	Department of Transportation
DRCOG	Denver Regional Council of Governments
DTD	Division of Transportation Development
dTIMS	Deighton's Total Infrastructure Management System
EMAC	Equipment Maintenance Advisory Committee
EPD	Environmental Product Declarations
ERF	Essential Repair Findings
ERP	Enterprise Resource Planning
ESAL	Equivalent Single Axle Load

FAST	Fixing America's Surface Transportation Act (2015) (federal)
FASTER	Funding Advancement for Surface Transportation and Economic Recovery (Colorado)
FHWA	Federal Highway Administration
FMCSR	Federal Motor Carrier Safety Regulation
FTA	Federal Transit Administration
GHG	Greenhouse Gas
GIS	Geographic Information System
HPTE	High-Performance Transportation Enterprise (Colorado)
HPMS	Highway Performance Monitoring System
HUTF	Highway Users Tax Fund (Colorado)
IIJA	Infrastructure Investment and Jobs Act (2021) (federal, also see BIL)
IP	Internet Protocol
IRI	International Roughness Index
ISO	International Organization for Standardization
ITS	Intelligent Transportation Systems
LCP	Life-Cycle Planning
LCCA	Life-Cycle Cost Analysis
LOR	Level of Risk
LOS	Level of Service
NHS	National Highway System
OFMB	Office of Financial Management and Budget
MAP-21	Moving Ahead for Progress in the 21st Century Act (2012) (federal)
MLOS	Maintenance Levels of Service
MODA	Multi-Objective Decision Analysis
MPA	Maintenance Program Area
MPB	Multimodal Planning Branch
MPO	Metropolitan Planning Organization
MTTR	Mean Time to Recovery
MUTCD	Manual on Uniform Traffic Control Devices for Streets and Highways
NBIS	National Bridge Inspection Standards
NHPM	National Highway Performance Measure
NHPP	National Highway Performance Program
NHS	National Highway System
NPM	National Performance Measure
NPMRDS	National Performance Management Research Data Set
NTIS	National Tunnel Inspection Specifications
OBU	On-Board Units
OEM	Office of Emergency Management
OFMB	Office of Financial Management and Budget
OTIS	Online Transportation Information System

PAMB	Performance and Asset Management Branch
PD 14.0	Policy Directive 14.0, Policy Guiding Statewide Plan Goals and Objectives
PD 1609.0	Policy Directive 1609.0, Transportation Asset Management
PM	Performance Measure
PMS	Pavement Management System
PPM	Property Program Manager
QMP	Quality Management Plan
RnR	Risk and Resilience (Tool)
ROW	Right of Way
RTD	Regional Transportation Director
RSL	Remaining Service Life
RSU	Roadside Unit
RWS	Road Weather Sensor
SAM	Structure Asset Management
SAMI	System for Asset Management and Inspection
SAP	Systems, Applications, and Products in Data Processing
SEA	Systems Engineering Analysis
SGA	Signal Asset Management
SGN	Statewide Traffic Signal Pool
SHS	State Highway System
SIMSA	System for Inspection and Asset Management of Structural Assets
SOV	Single Occupant Vehicle
SSA	Statewide Signal Asset Database
STBG	Surface Transportation Block Grant
STIP	Statewide Transportation Improvement Program
STP	Surface Treatment Program (Colorado)
STSP	Strategic Transportation Safety Plan (Colorado)
TAM	Transportation Asset Management
TAMOC	Transportation Asset Management Oversight Committee
TAMP	Transportation Asset Management Plan
TARE	Total Annualized Risk Exposure
TMC	Traffic Management Center
TPM	Transportation Performance Management
UPS	Uninterrupted Power Supply
VMT	Vehicle Miles Traveled
VMS	Variable Message Signs
VSF	Vehicle Storage Facility
WCI	Weighted Condition Index
WIG	Wildly Important Goal
ZEV	Zero-Emission Vehicle

APPENDIX A. ASSET PLANS



From massive tunnels to the smallest traffic cameras, modern transportation systems are more than just roads and bridges. CDOT's Transportation Asset Management (TAM) Program includes 12 asset programs that make safe and efficient travel to all corners of Colorado a reality. While pavement and bridges comprise the main TAMP, this appendix provides plans for other asset types critical to the highway system.

The 10 asset programs discussed in this appendix include:

BUILDINGS, which protect snow plows and other essential maintenance equipment, as well as provide office space.

CULVERTS, which provide drainage to keep highways clear of water and debris.

FLEET/ROAD EQUIPMENT, which includes snow plows and other equipment to maintain our highways, such as by removing snow and ice or striping the roadway.

GEOHAZARDS ASSETS, which keep travelers safe from rockfalls and landslides in the state's mountainous terrain.

INTELLIGENT TRANSPORTATION SYSTEMS (ITS) DEVICES, including cameras and wireless technologies, which help workers respond to accidents, provide critical traffic information, and more.

MAINTENANCE LEVELS OF SERVICE, which funds maintenance activities such as roadway striping, snow and ice removal, and more to ensure the highway system is safe and in a state of good repair.

REST AREAS, which provide safe and secure restrooms and other services to allow travelers to take a break on long journeys.

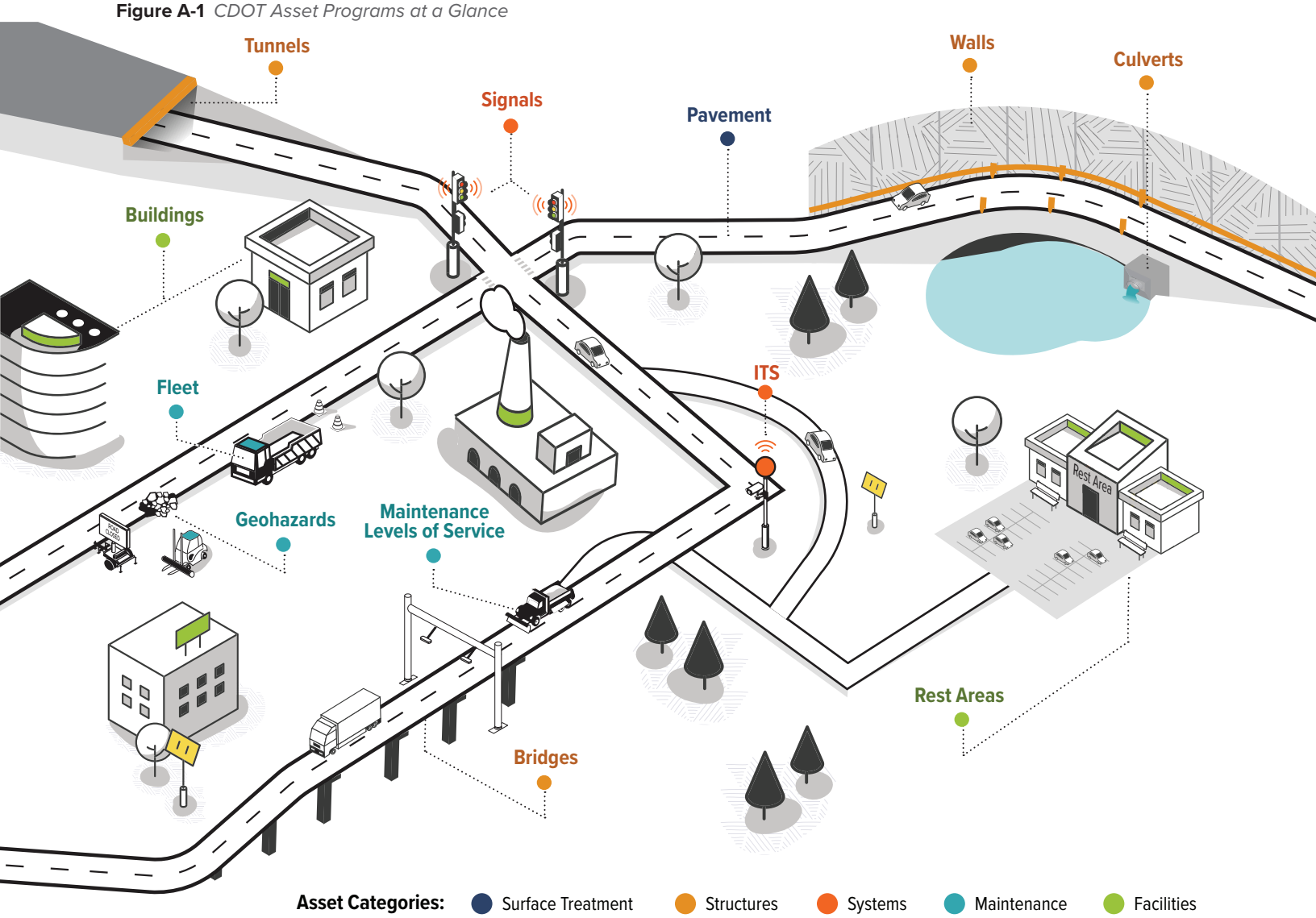
TRAFFIC SIGNALS, which ensure the safe movement of vehicles, protect pedestrians, and help prevent congestion.

TUNNELS, which safely connect the highway system and create efficient routes to ease passage across the Rocky Mountains and throughout the state.

WALLS, including retaining walls, bridge walls, and noise walls—that support roads and bridges and mitigate traffic noise.

The asset plans that follow describe the inventories, performance measures, strategies, policies, and procedures that help maintain the highway system. **Figure A-1** helps illustrate the role that each asset program plays in the system.

Figure A-1 *CDOT Asset Programs at a Glance*



STRUCTURE OF THE APPENDIX

Each asset plan that follows includes:

1. A brief introduction to the assets managed in the asset program.
2. Performance objectives, measures, and targets.
3. High-level documentation of the asset-program inventory and condition.
4. How the assets are planned for and managed throughout their life-cycles.
5. Major risks and how those risks are to be managed.
6. A financial plan for 2022-31 (10 years).
7. Most asset plans include an asset valuation, or a reason one was not included.
8. Investment strategies for the 10-year time horizon of the TAMP.
9. An analysis of the performance gap, if any, envisioned over the next 10 years if the Financial Plan does not provide sufficient funding to achieve performance targets.
10. Planned improvements to staffing, processes and technology.

MANAGING OTHER CDOT ASSETS

CDOT's TAM Program plays a critical role in helping achieve the Department's mission of providing a transportation system that effectively and safely moves people, goods, and information by ensuring the state of good repair of all assets across Colorado's transportation system. Asset management at CDOT generally follows an annual, cyclical process that begins with taking inventory of assets each year. Once the inventory is collected, CDOT begins developing new forecasts, determining new budgets and treatment lists, and delivering new projects for each asset program. **Figure A-2** illustrates how CDOT manages the 10 asset programs in this appendix.

POLICY DIRECTIVE 14.0 PERFORMANCE MEASURES

The asset plans follow goal areas established in CDOT's Policy Directive (PD 14.0) — asset management, safety, and mobility (see **Figure A-3**).

Each goal area contains multiple performance measures and targets that allow CDOT to evaluate statewide efforts in effectively managing the highway system. The targets are used to help determine funding levels for each of the 12 asset programs within CDOT's TAM Program.

Figure A-2 *Asset Management Cycle at CDOT*

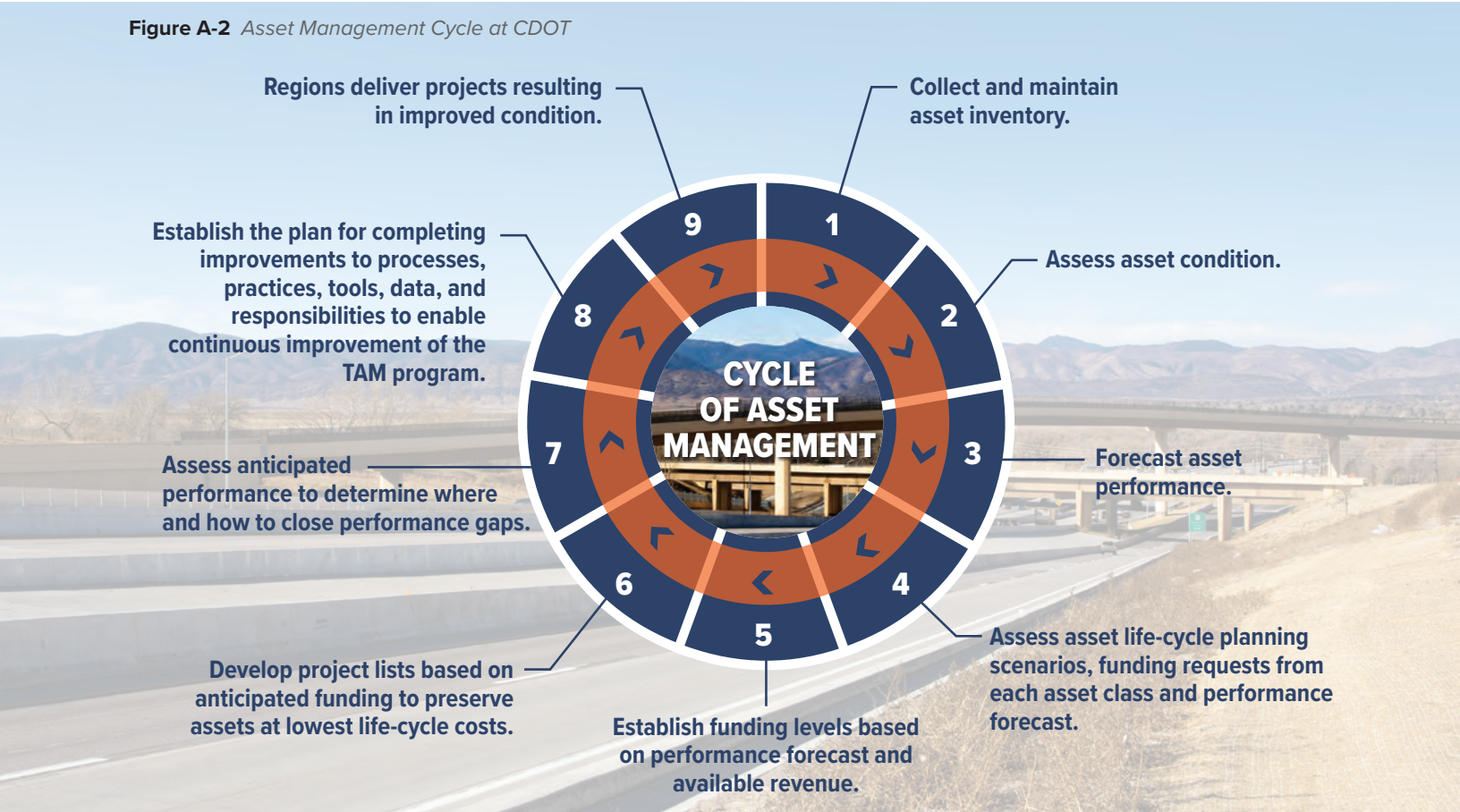


Figure A-3 *PD 14.0 Goal Areas*

Each asset program has at least one performance measure and target that generally relate to the assets' condition. In a few cases, the measure is related to an operational standard, such as overall maintenance levels of service, or the level of service for snow and ice removal.

CDOT assets of all types are being managed to support the goal areas of safety and mobility. Examples include:

- Reducing the risks from geohazards.
- Removing snow and ice promptly.
- Assuring that traffic signals are in working order.
- Ensuring that ITS devices are available to support faster incident response and clearance, mitigate weather-related crash patterns, and provide critical traffic information to vehicle operators.

In general, sustaining all programs of roadway and roadway-related assets in a state of good repair helps ensure the reliability of the highway system as a whole.

Table A-1 presents the PD 14.0 performance targets and 2021 performance for the 10 asset programs described in this appendix. Within the table, green shading indicates that 2021 performance met the target, while red shading indicates the target was not met. Several asset programs employ additional performance metrics in the life-cycle management of their respective assets, as described in the individual asset plans.

Table A-1 *CDOT Asset Management Metrics, Targets, and Performance*

Asset	Measure	Target	2021 Performance (unless stated)
Buildings	Percentage of buildings with a letter grade of C or better	≥85%	49%[1]
Culverts	Percentage of culverts in Poor condition (have a culvert rating of 4 or less)	≤5%	5.4 %
Fleet	Average percentage of expended useful life for fleet vehicles	≤75%	69%
Geohazards	Percentage of hazardous road segments at or above risk grade B	≥85%	75%
Intelligent Transportation Systems	Average percent useful life expended of ITS equipment	≤90%	70%
Maintenance Levels of Service	MLOS grade for the state highway system	≥B-	C-
	LOS grade for snow and ice removal	≥B	C-
Rest Areas	Percentage of rest areas with a C grade or better	≥90%	63%
Traffic Signals	Percentage of signal infrastructure in Severe condition	≤2%	7%
Tunnels	Percentage of network tunnel length with all elements in equal or better condition that 2.5 weighted condition index	≥75%	39% (2020)
Walls	Percentage of CDOT-owned walls, by square foot, in Poor condition (have a rating of 4 or less)	≤2.5%	3.5%

1 Change in condition grading implemented in 2020

TAM PROGRAM

Assets described in this appendix follow the organizational and governance structure for asset management described in Section 2 of the TAMP. The Transportation Commission sets the TAM Program's strategic direction—adopting performance metrics, targets, and annual planning budgets for all asset programs.

The TAM Program is part of the Performance and Asset Management Branch (PAMB) in CDOT's Division of Transportation Development (DTD). The core responsibilities of PAMB include asset management, as well as risk and resilience management, performance management, and economic analysis.

Each asset program in CDOT's Transportation Asset Management (TAM) Program is led by a designated statewide asset manager. The asset manager leads the creation of strategies to meet performance objectives, inventory and condition documentation, and life-cycle planning, budgeting, and programming. In many cases, the asset manager also leads life-cycle management and capital-project planning and delivery for their respective assets. For some assets, responsibility for these activities may be shared between more than one individual or group, and between CDOT Headquarters staff and CDOT Regions, as described in the individual asset plans.

PAMB works closely with the Headquarters-level asset managers for each of the 12 asset programs in formulating CDOT's asset-management program. This includes identifying budget needs and the life-cycle planning approaches described in the main TAMP and this appendix. That work is facilitated by a formal staff-level TAM Working Committee, consisting of the PAMB Manager, TAM Program Manager, and managers for the 12 asset programs. The TAM Working Committee assists CDOT in developing new asset-management processes and project lists, discussing asset-modeling systems, meeting FHWA asset management requirements, and addressing other issues raised by CDOT's TAM Oversight Committee (TAMOC).

The TAMOC consists of the Executive Director, Deputy Executive Director, Chief of Staff, Chief Engineer, Chief Financial Officer, Deputy Chief Engineer, Director of Transportation Development, Director of Project Support, and the five Regional Transportation Directors. The TAMOC meets monthly and is responsible for the initial[2] determination of how to distribute the TAM Cap (the total amount of funding for the TAM Program each year) among the 12 asset programs. The TAMOC also provides initial approval for performance metrics and targets for each asset program. And at least two of three members of The TAMOC—the Executive Director, Chief Financial Officer or Chief Engineer—must approve TAM treatment lists.

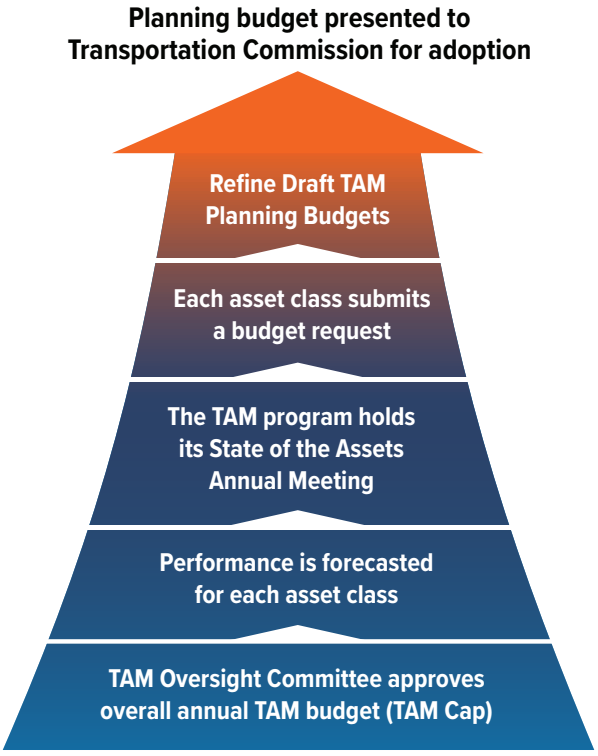
CDOT uses its Asset Investment Management System (AIMS) software to forecast asset performance. The program uses past performance data, deterioration curves for each asset, and treatment information to forecast an asset's future condition.

The AIMS analysis allows the TAM Program to compare different budget scenarios to determine how much funding an asset should receive—based on the effect that additional funding would have on performance. CDOT also uses the tool to compare the relative benefits of changes in funding allocations across asset programs. For a projected budget, CDOT uses the AIMS analysis results to determine the most cost-effective treatments and strategies that maximize network performance over the life of assets.

ANNUAL BUDGETING PROCESS

Processes described in the TAMP—including investment strategies and processes to establish planning budgets for CDOT's asset programs—lead toward development of a rolling, four-year program of asset management treatments, or a project list. This list represents the projects that CDOT intends to deliver for asset management. An update to the list is developed every year. **Figure A-4** outlines the planning budget process followed annually.

Figure A-4 *Planning-Budget Process*



2 Planning budgets, metrics and targets receive final approval/adoption from the Transportation Commission.

ASSET INVENTORIES

The 10 asset programs in this appendix comprise inventories of thousands of individual assets. CDOT uses a variety of software and databases to record and track its assets and their condition, and in some cases, for project and maintenance work-management purposes. Some asset programs are subject to rigorous auditing processes to confirm and clarify inventories. In some cases, this has led to reclassification of what assets are included in inventories. **Table A-2** provides a summary of the total number of assets currently managed in each asset program.

Table A-2 *Total Asset Inventory by Asset Program*

Asset Program	Inventory
Buildings	1,009
Culverts	5,946
Fleet	3,219
Geohazards	3,437 1/10-mile segments
Intelligent Transportation Systems	2,146 devices; 1,532 network-gear items; 1,624 miles fiber; 31 ITS facilities
Maintenance Levels of Service	10.3 million ft. guardrail (metal, concrete, cable); 211,738 signs; 48,928 miles striping; 34,735 pavement markings; 27,736 high mast and roadway lighting poles; 46,305 attenuators/end treatments; 493,000 delineators; 58.5 million linear ft. fence
Rest Areas	26 rest areas; 117 ancillary structures
Traffic Signals	1,852
Tunnels	20
Walls	2,928; 14.0 million square ft.

CROSS-ASSET ROLES OF MLOS AND GEOHAZARDS

The MLOS and Geohazards programs have unique functions that set them apart from the 10 other asset programs. Those functions relate to specific aspects of life-cycle management across asset programs—including routine maintenance of some other asset programs in the case of MLOS, and for protecting other asset programs in the case of the Geohazards program.

MLOS

The Maintenance Levels of Service (MLOS) program, sometimes referred to as "Maintenance" within CDOT, has multiple roles. MLOS provides routine and preventive maintenance services for asset programs managed by others, including the Pavement (surface treatment), Bridges, Tunnels, Rest Areas, Buildings, Traffic Signals, and Geohazards programs. In addition, MLOS has operational responsibility for activities such as roadway striping and snow and ice removal. This includes managing patrols who staff snow plows to keep the roadways open.

The MLOS program's two performance measures relate to the maintenance of the assets managed by others and to its snow and ice removal services.

There also are safety and traffic-related assets for which MLOS is totally responsible, including guardrails, signs, pavement striping, and roadway lighting. For these assets, MLOS manages the asset life cycle from installation/construction, through operation and maintenance, to disposal and replacement.

GEOHAZARDS

The Geohazards program is responsible for identifying and managing geologic risks to the highway system posed by rockfalls, embankment distress, landslides, debris flows, sinkholes, and failures of constructed soil slopes. The program implements risk-mitigation treatments on strategic highway segments and corridors, protecting pavement, bridges, and all the other asset programs potentially impacted by geohazards.

ASSET VALUATION FOR OTHER ASSET PROGRAMS

Asset valuation is the process of estimating the current monetary value of an agency's assets. Knowing the value of assets helps transportation agencies understand the appropriate balance between maintaining well-performing assets and repairing or replacing deteriorating assets.

CDOT's approach to assessing asset values can be summarized as follows:

> asset value ≈ gross replacement cost, adjusted for age, quality/features, inflation, condition, obsolescence, and other factors.

Because asset values deteriorate during service due to age, use, damage, and obsolescence, current asset value is not equal to replacement cost.

The methodology for valuing asset programs differs by asset type:

- Bridges, culverts, pavements, tunnels, and walls primarily use a condition-based approach.
- Fleet, ITS, and signals primarily use linear depreciation.
- Buildings use insured value.

Asset valuation is the process of estimating the current monetary value of an agency's assets.

Asset values deteriorate during service due to age, usage, damage, and obsolescence.

LIFE-CYCLE PLANNING

The plans for different asset programs reflect a range of life-cycle management approaches including:

- **Condition-based**: The condition of an asset is measured and used to forecast performance, select treatments, and identify the onset of failure.
- **Interval/age-based**: Asset performance data and/or manufacturers' life-expectancy estimates are used to establish a time interval representative of the service life beyond which the cost of asset failure outweighs the cost of replacement.
- **Reactive:** Minimum acceptable condition thresholds are established to determine which treatment is performed to fix a problem after it has occurred.

RISK AND RESILIENCE APPROACH TO OTHER ASSETS

The major threats to each asset program are presented in the respective asset plans in this appendix.

CDOT's risk management approach, described in Section 6 of the TAMP, includes the management of risk across various levels—agency, programmatic, and project/asset. The approach also includes the development and management of risk registers, and decision-making that incorporates risk management and resilience. For asset management specifically, CDOT is refining processes to incorporate risk into treatment selection and prioritization.

For this TAMP, CDOT has reassessed the threats contained in the risk register for each asset program. One of the objectives of the development of the risk registers is to provide common definitions of consequences and consideration across all asset programs, to better understand scaling measures, and to capture vulnerabilities. The risk assessment methodology incorporates measures and a scoring rubric for the level of risk; likelihood of the event/occurrence; direct consequences for safety, mobility, asset damage, and other financial impacts; as well as the dollar value of the consequences and vulnerability.

FINANCIAL PLANS FOR OTHER ASSETS

The asset plans in this appendix present the financial plan for each asset class, by year.

Section 7 of the TAMP (see page 52) documents the funding sources available to CDOT for all functions of the Department, including sources for the total budget, or "TAM Cap," of the overall TAM Program.

The Financial Plan sections of the asset plans in this appendix describe the funding sources available to achieve performance targets for each asset class. The TAM Cap is the largest consistent funding source for most asset classes.

Each asset plan shows anticipated budgets for the next 10 years for each of the 12 asset programs. For the first four years of this period, the planning budgets have been adopted by the Transportation Commission. For years beyond fiscal year 2025, the budget shown is typically held at 2025 levels.

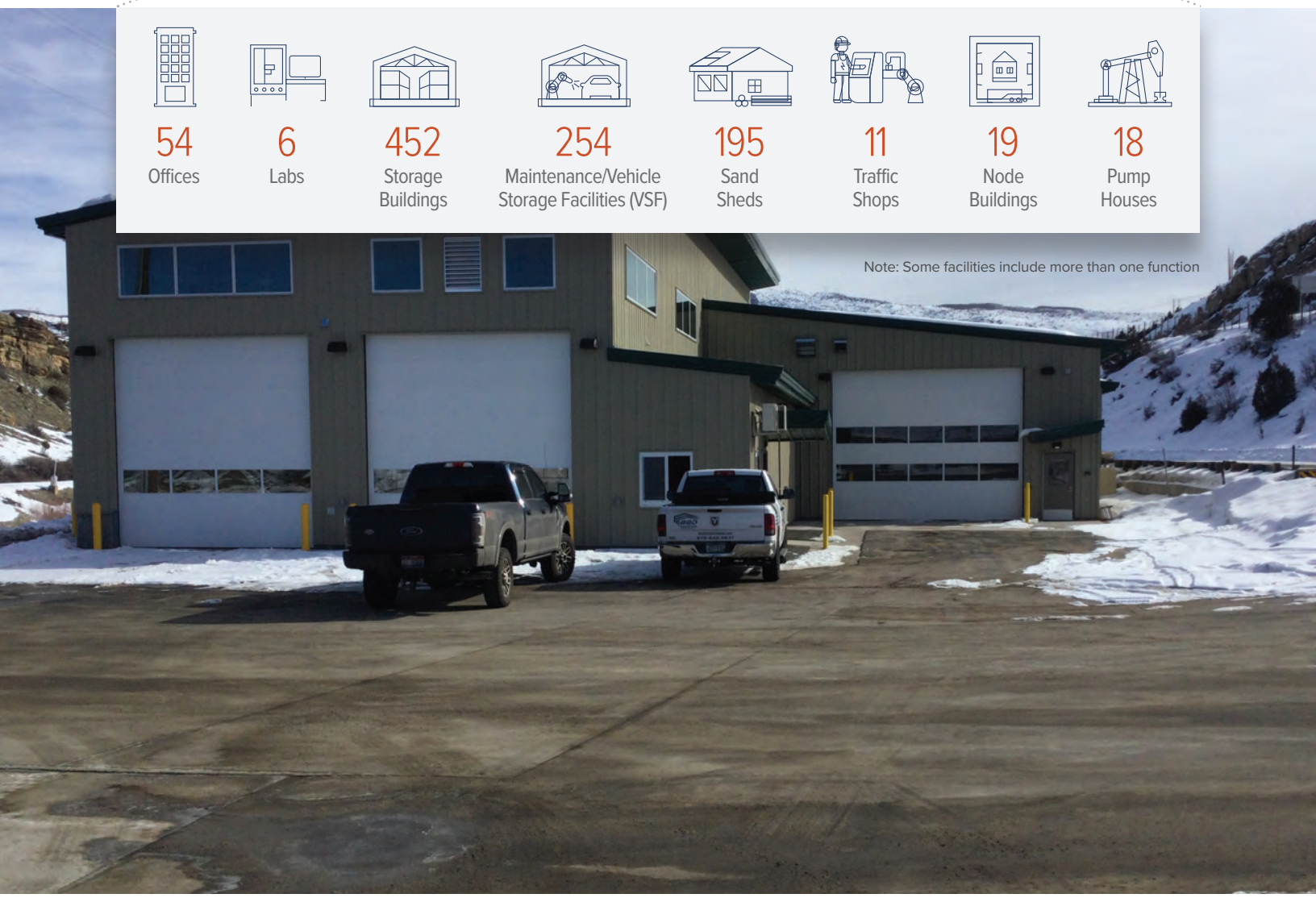
A-1. BUILDINGS

Buildings shelter some of CDOT's most critical assets but are also managed as an asset class in their own right. The Department's Buildings program manages more than 1,000 buildings statewide. Most of these structures safely store and maintain essential vehicles such as snow plows, as well as equipment and supplies, ensuring the Department is at-the-ready for snow storms and emergencies. Offices for administrative staff and laboratories for technicians are also included in this asset class.

CDOT's Buildings program employs a comprehensive asset-management process closely aligned with the process described in the Introduction to the Asset Plan Appendix.

A majority of CDOT buildings are rapidly approaching or have approached the end of their service life, and therefore require replacement. Functionality is critical to the importance of these assets, and CDOT has refined its assessments of buildings to consider functionality as well as condition. Should current funding levels of about $16 million to $17 million per year be sustained, CDOT models forecast a shortfall in the cost to meet the primary buildings performance target over the next decade (see **Figure A.1-8** of this asset plan). Planned investments, if funding is provided, will include major repairs; wash bays, lean-to structures, and other projects; as well as nearly 30 replacement projects over the same period.

Figure A.1-1 *Buildings Inventory at a Glance*



PERFORMANCE MANAGEMENT

CDOT monitors buildings using its performance-management framework, using quantitative measures and a performance target. The Department uses performance information to inform funding decisions and to track how assets are supporting the agency's strategic goals and transportation services provided to the public.

POLICY DIRECTIVE 14.0 PERFORMANCE MEASURE

The asset management program for buildings contributes to goal areas in Policy Directive 14.0 (PD 14.0)— asset management, safety, and mobility. CDOT buildings provide safe working conditions for employees and proper storage and maintenance for equipment that ensures the safety of highway users. Buildings support mobility in several ways. For example, maintenance-patrol buildings expedite snow-event response times, slow deterioration of equipment, and increase worker safety and efficiency. These benefits help ensure a quick return to normal traffic operations.

The PD 14.0 performance measure for maintaining buildings in a state of good repair is the percentage of assets with a letter grade of C or better, on an A to F scale. The letter grade considers building performance; structural integrity; mechanical, electrical, and plumbing systems; as well as overall site condition. The process for assessing condition through letter grades is described in the Inventory and Condition section.

Table A.1-1 shows the PD 14.0 target and 2021 performance for buildings. Storage buildings, as well as employee housing, are excluded from the analysis. Storage buildings are assessed separately, for structural integrity.

CDOT considers buildings to be in a state of good repair if 85 percent are assessed at grade C or better.

The current (2021) percentage of buildings in condition grade C or better is 49 percent, well short of the target of 85 percent. See the Performance Gap Analysis section of this Asset Plan for a discussion of this shortfall.

Table A.1-1 *Performance Metric and Target for Buildings*

BUILDINGS

Measure	Target	2021 Performance
Percentage of Buildings with a letter grade of C or better	85%	49%

INVENTORY AND CONDITION

CDOT tracks the inventory of its buildings using a unique number for each building. This information is contained in CDOT's Building Condition Dashboard, as well as in SAP, the Department's financial system. Annually, the Department uses the Survey123 mobile application to assess building condition. An overall letter grade is assigned based on multiple criteria, including structural integrity and overall site condition.

INVENTORY

CDOT owns and maintains 1,009 buildings. These buildings include vehicle-storage facilities, maintenance shops, traffic shops, sand sheds, storage buildings, offices, and lab facilities. This inventory is shown in **Table A.1-2**. The totals exclude CDOT employee housing, which includes 93 employee housing units—apartments, houses, and duplexes—as well as mobile-home pads with power, gas, water, and sewer service. Housing is managed at the CDOT Region level.

Table A.1-2 *Inventory of Building Assets*

Building Type	Current Count
Lab	6
Maintenance/Vehicle-Storage Facilities	254
Office	54
Sand Shed	195
Storage Buildings	452
Traffic Shop	11
Node Buildings	19
Pump Houses	18
Buildings Total	1,009

Maintenance/Vehicle-Storage Facilities and Traffic Shops: These building types are typically heated, pre-engineered metal or concrete masonry unit (CMU) buildings with multiple vehicle storage bays for storage of essential equipment. Most have restrooms, and some have office and/or breakroom structures attached for maintenance staff administrative functions.

Sand Sheds: These buildings are typically pre-engineered metal buildings or hoop-framed canvas atop concrete walls. They have a large opening with roll-up overhead doors for functional offloading of sand into plow trucks and protection of sand from direct precipitation, thereby preventing runoff into environmentally sensitive areas.

Examples of Building Assets

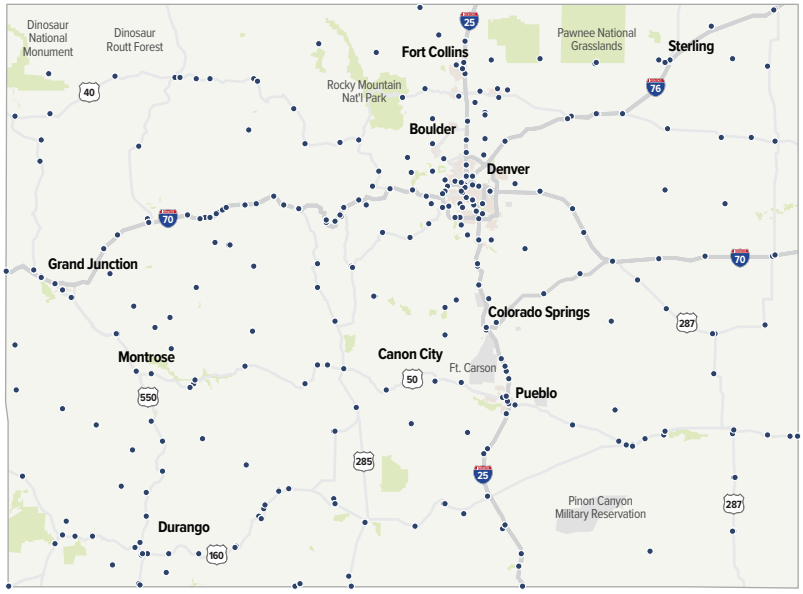
The buildings inventory is managed using unique building numbers that are assigned by Property Management and tracked in the Buildings Dashboard and the SAP financial management system. Throughout the year, the buildings inventory is updated using CDOT's Property Master Change Form #1152. The Office of Risk Management and CDOT's Division of Accounting and Finance (DAF) are notified monthly of inventory changes. The risk office uses building data provided to update, add, or delete insurance coverage for buildings, and DAF uses the data to track building depreciation.

While the inventory presented in **Table A.1-2** excludes employee housing, for insurance purposes, all buildings, including employee housing, are included in the buildings inventory.

Figure A.1-2 presents the location of buildings, as shown in CDOT's Building Condition Dashboard.

A building number is required for the State Office of Risk Management to insure any building and its contents.

Figure A.1-2 *Buildings in the CDOT Buildings Inventory*

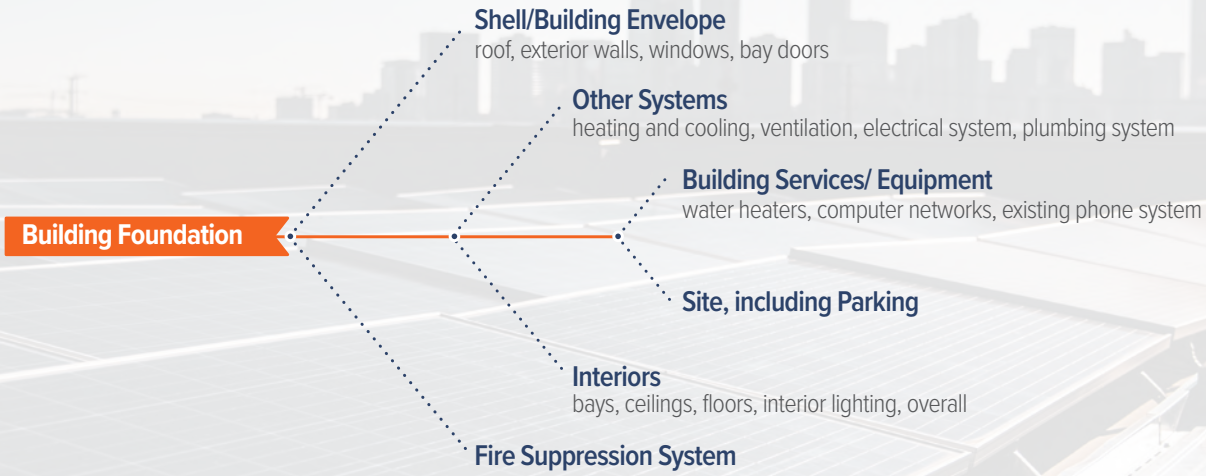


ASSET HIERARCHY

To understand the performance of buildings assets, CDOT tracks the condition and/or functionality of the major systems and other components that comprise each building, including the information presented in **Figure A.1-3**.

The building foundation, components of the building envelope, and the fire-suppression system are all considered critical components. For traffic shops, vehicle-storage facilities, and maintenance facilities, radiant-heat systems and wash bays are also considered critical components.

Figure A.1-3 *Asset Hierarchy*



CONDITION

"Building condition" refers to the letter grade given to each building based on information gathered during an annual condition assessment. The annual assessment considers the building components by customized categories that are consistent with the building type and purpose. Categories can include structural, systems, compliance, component, building services, and site.

Depending on the building type, the component categories can include structural, systems, compliance, components, building services, serviceability, amenities, and site.

The category most important for each building type accounts for most of the grade.

Two dedicated staff members inspect each building annually, using a mobile application created by ESRI, using the Survey123 platform. The use of dedicated staff ensures consistency in the quality of condition ratings among the different buildings within the portfolio and over time.

The scores given to components within each category are added together to provide a category score. Each category score is then multiplied by its designated weight, and a letter grade is assigned to each category based on the weighted category score. The category scores are then used to calculate the building's overall score. All scores are totaled and assigned a letter grade based on traditional scoring presented in **Table A.1-3**.

Figure A.1-4 illustrates the Buildings program's condition-assessment methodology—how component scores are calculated and rolled up into category ratings (i.e., scores and grades), and how category ratings are rolled up into building ratings.

CONDITION TRENDS

While trends indicate that the condition of buildings was relatively stable through 2019, as shown in **Table A.1-4**, a change in how conditions were assessed led to a sharp drop between 2019 and 2021.

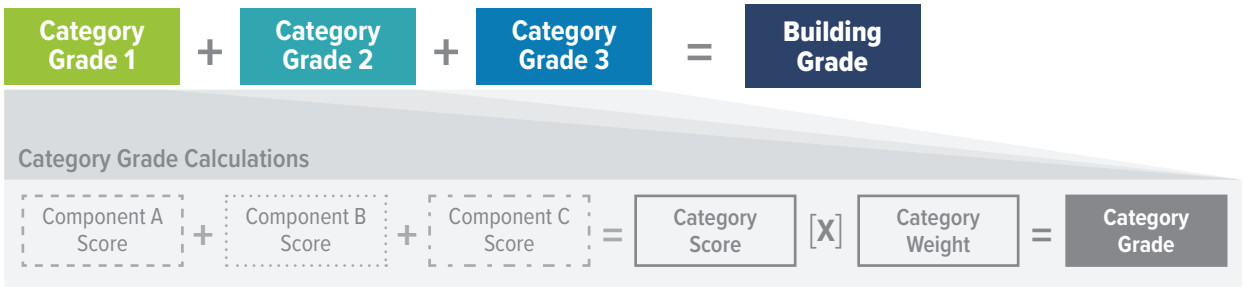
Table A.1-4 *Buildings Condition Trends*

Historical Performance | % of Buildings Rated C or Better				
2017	2018	2019	2020[1]	2021
83%	80%	80%	55%	49%

Table A.1-3 *Definitions of Building Letter Grades*

Grade	Score	Definition
A	90—100	Excellent—Condition appears new, no defects.
B	80—89	Good—Good condition, shows slight wear.
C	70—79	Average—Some noticeable wear.
D	60—69	Fair—Noticeable wear, needs repair.
F	59 and below	Poor—Extensive wear, needs to be replaced.

Figure A.1-4 *Condition Assessment Methodology*



1 Methodological change.

In 2021, the Buildings program implemented "syllabus"-type scoring in which one single category grade accounts for much of the overall grade, as follows.

- **Vehicle-Storage Facilities/Maintenance/Traffic buildings**—70 percent of the score is dependent on the Service category grade and 30 percent on all other grades.
- **Sand Sheds**—80 percent of the score is dependent on the Structural category score and 20 percent on all other grades.
- **Offices**—45 percent of the score is dependent on the Structural score and 55 percent on all other grades.

For Vehicle-Storage Facilities, the Service category letter grade reflects how well these buildings are protecting equipment assets. One singular component—size of the bays and bay doors—can render them non-functional.

For sand sheds, the greater weight given to the Structural category resulted in a sharp drop in the 2021 condition rating.

ASSET VALUE

CDOT estimated the value of its buildings assets in early 2022. The current replacement value is determined by the cost per square foot or vehicle bay. This replacement value is $1.5 billion.

The risk/insured value was used to calculate current asset value. The estimated current value of buildings assets is $613 million.

LIFE-CYCLE PLANNING

The Buildings program strives to sustain or improve the functionality of CDOT's buildings inventory. CDOT develops a maintenance plan for buildings with grades A to D. Buildings with a grade F are considered for replacement, demolition, or repurposing, rather than repair. An annual plan for maintenance, code reviews, and capital improvements leverages findings from an annual condition assessment, as well as treatment recommendations from CDOT's Asset Investment Management System (AIMS) model.

LIFE-CYCLE PLANNING

CDOT's uses a condition-based approach to the life-cycle management of buildings assets, and also incorporates functionality assessment.

Roughly half the buildings inventory—520 assets—are included in the AIMS analysis as a basis for financial planning and investment decisions. Those include vehicle-storage facilities, mechanics' buildings, traffic buildings, sand sheds, offices, and lab facilities. Excluded are employee housing, pump houses, node buildings, and storage. Storage buildings are non-heated buildings that maintenance staff have constructed, or prefabricated sheds that maintenance staff have purchased to store equipment and consumable items like mowers and fertilizer. Employee housing is funded outside of the Buildings program, through the Maintenance Levels of Service (MLOS) budget.

BUILDINGS LIFE-CYCLE MANAGEMENT APPROACH

The findings of the annual condition assessment described in the Inventory and Condition section of this Asset Plan informs the selection of appropriate treatments within the AIMS model. AIMS uses the current-condition rating of the asset—along with deterioration models specific to the type of building, its purpose, and its age—to develop treatment recommendations over a 20-year timeframe.

On an annual basis, the Buildings Program Architect assesses the AIMS treatment recommendations to develop an investment-strategy list. The architect then undertakes a needs assessment for each project in the list to determine the most appropriate capital improvement. Once the needs assessment is complete, the investment strategy is updated by the Buildings Asset Manager for approval by the Director of Maintenance and Operations and the Property Program Manager. The approved investment strategy is included in the Annual Property Plan.

The modeling from AIMS also provides a roadmap of treatments projected to be needed for each building in the coming years. The modeling is updated annually, and treatments needed portfolio-wide can be estimated and programmed for the following years.

PROGRAM DECISION-MAKING

TREATMENT SELECTION

Treatments are used to correct the condition of an asset or to prolong its life. The AIMS modeling generates strategies composed of one or more treatments over the analysis period. While historic funding priorities have led to a preponderance of replacement projects, the number of treatments within the model has recently been expanded to provide more specific treatment recommendations that will maximize budget allocations and provide more accurate performance modeling. Treatments recommended for the next 10 years from the AIMS model ran in 2022 included:

- **Major repair:** Any treatment that does not add square footage to a building. Can include restroom remodels, roof replacements, HVAC upgrades, etc.

- **"Lean-to" additions:** Square footage added to maintenance buildings, vehicle-storage facilities, or traffic shops for offices, restrooms, or breakrooms.
- **Additions:** Square footage added to the front or back of maintenance buildings, vehicle-storage facilities, or traffic shops to increase the size of vehicle bays. This treatment is only applied to buildings with bays at least 20' wide. While the width of bays cannot be changed, the length can with certain construction types.
- **Conversion to wash bay:** A treatment that changes a vehicle bay in a maintenance building, vehicle-storage facility, or traffic shop into a waterproof bay complying with National Electrical Manufacturer Association requirements for wet environments. Wash bays are used to wash and store essential equipment for proper maintenance.
- **Replacement:** Reconstruction of an existing building on the same site.

The determination of which types of treatment activities are appropriate to each category of work is further governed by the Property Plan and Policy Directive 60.1 of the Office of the Chief Engineer/ Property Management.

Maintenance & Repair

"Controlled maintenance" and "deferred maintenance" projects constitute between 15-20 percent of annual funds for the Buildings program.

Controlled maintenance includes corrective repairs or improvements that increase the safety or operating efficiency of a building and are necessary for health, life safety, and code compliance of A, B, and C rated buildings. Controlled maintenance funds are intended to maintain the building and prevent it from slipping to a lower letter grade.

Deferred maintenance projects are corrective repairs or improvements for existing facilities with a D rating meant to elevate the overall building condition and prevent the building from falling to an F rating. The Superintendent of each of CDOT's eight Maintenance sections submits their priorities for these controlled and deferred maintenance projects that are then reviewed and approved by the Buildings Asset Manager, as shown in **Figure A.1-5**.

Figure A.1-5 *Review-and-Approval Process for Controlled-and-Deferred Maintenance Projects*

Rehabilitation, Reconstruction, and Replacement

Some 80 to 85 percent of funds for the Buildings program is allocated for capital improvements, such as rehabilitations, reconstructions, and replacements. This includes any site work needed to meet current environmental standards such as re-grading for proper drainage and installing stormwater treatment and storage devices like vegetated swales (drainage channels). Capital-improvement projects are established each fiscal year for the fiscal year five years beyond, thus resulting in a continuous five-year planning cycle. The process for developing a capital improvement project is shown in **Figure A.1-6**.

Figure A.1-6 *Capital-Improvement Project: Development and Delivery*

New Construction

The Buildings program is responsible for the construction of all CDOT buildings; however, funding for new buildings not included in the AIMS analysis does not come from the TAM Program. TAM program funding is intended to maintain and improve the existing inventory. Functional expansion of the inventory through the addition of new buildings that are not replacing one already in CDOT inventory, are funded through other means.

New Construction: *CDOT Headquarters*

CDOT's Headquarters (above), in the Sun Valley neighborhood, replaced CDOT's former headquarters building and Region 1 offices in 2018.

The types of asset management treatments undertaken by CDOT for buildings are classified according to FHWA work types in **Table A.1-5** below.

Table A.1-5 *Buildings Life-Cycle Management Activities*

Work Type	CDOT Activities	Indicative Costs
Maintenance (Reactive/ Corrective)	Corrective and Deferred Maintenance refers to corrective repairs or improvements that increase the safety or operating efficiency of a building and prevent deterioration to an F-condition rating. This includes projects such as: » Carbon monoxide (CO) and nitrogen dioxide (NO2) sensor repair and replacement » Concrete apron repairs, panel replacement, and wing wall replacement » HVAC yearly service » Interior and/or exterior painting » Metal or fabric panel replacement » Minor electrical repairs » Minor room remodel » New hardware for doors » New flooring » New plumbing fixtures » New roofs » Overhead doors: Annual service, repairs, and panel replacements » Plumbing repairs » Rain gutters and snow guards » Roof repairs » Septic tank: Annual service, repair, and replacement (not pumping) » Upgrading of manual gate to an electric gate	$122/sq. ft.
Reconstruction	Reconstruction includes renovations of buildings that increase square footage, life expectancy, operating efficiency, or capacity. This work type also refers to renovations that add value to land and buildings with costs for design and construction exceeding $50,000.	$200-260/sq. ft.
Replacement	This work type refers to the complete replacement of existing buildings on CDOT-owned land due to program changes, functional obsolescence, or the complete deterioration of building conditions.	$350/sq. ft.
New Construction	New construction refers to adding new buildings required due to functional expansion of maintenance patrols and other factors.	

RISK MANAGEMENT

The Buildings program manages risk across multiple levels—agency, programmatic, and project/asset. Section 6 of the main TAMP document provides more information about CDOT's risk-management methodology and processes.

The Buildings program maintains a register of risks to its overall program and projects. Top risks are shown in **Table A.1-6**.

Table A.1-6 *Top Buildings Risks*

Risk Level	Threat/ Opportunity	Risk Score[2]	Risk-Management Strategy
Program	Building-materials availability (or lack thereof), impacting costs and operations.	67.5 (T)5 x (C)2.7 x (V)5	Tolerate
Program	Changing strategic direction, from leadership, both organization and government.	57.5 (T)5 x (C)2.3 x (V)5	Tolerate
Project	Changing functional needs for the buildings, for a new or different location (e.g., combining maintenance patrols). A building on an existing site is no longer functional.	52.8 (T)4 x (C)3.3 x (V)4	Tolerate

2 Risk Score = Threat Likelihood (T) * Total Consequence and Consideration Score (C) * Vulnerability (V)

FINANCIAL PLAN

CDOT creates planning budgets for buildings and other asset-management programs four years in advance. For this financial plan, CDOT has carried forward fiscal year 2025 planning-budget levels for fiscal years 2026-31. These estimates, combined with CDOT's life-cycle management approaches, inform the investment strategies intended to achieve system-wide asset performance goals while minimizing costs.

FUNDING SOURCES

The Buildings program receives a portion of the funds for CDOT's overall Transportation Asset Management (TAM) Program to fund rehabilitation and reconstruction work types described in the Life-Cycle Planning section.

Additionally, CDOT's Maintenance Levels of Service program funds routine maintenance, preservation treatments, and repairs for buildings that do not require engineering. Those activities are part of the MLOS asset plan and its financial plan.

PLANNED FUNDING

CDOT estimates steady funding for buildings over the current decade. The TAMP 10-Year Financial Plan for buildings is shown in **Table A.1-7.**

Table A.1-7 *Financial Plan for Building Assets (in Millions)*

FY22	FY23	FY24	FY25	FY26	FY27	FY28	FY29	FY30	FY31
$16.7	$17.8	$17.0	$15.5	$15.5	$15.5	$15.5	$15.5	$15.5	$15.5

INVESTMENT STRATEGIES

CDOT forms asset-investment strategies based on its financial plan and life-cycle management strategies, which are designed to meet system-wide performance goals while minimizing life-cycle costs. Investment strategies delineate different types of work to be performed across CDOT's buildings assets over a 10-year period.

BACKGROUND: DETERMINING INVESTMENT STRATEGIES

The development of investment strategies begins each year when the current building inventory and condition data are loaded into the AIMS model. The model then forecasts building scores and conditions for the next 20 years. AIMS then generates a list of possible strategies for each building. These strategies may include several rehabilitations, upgrades, additions, and replacement treatments, based on business rules created by CDOT. Finally, the model will return a set of strategies that optimizes the benefit for any given budget. In FY22, the model provided a set of treatment strategies and a performance forecast given annual budgets of $15.5 million to $17.0 million, as assumed in the Buildings Financial Plan.

PLANNED INVESTMENTS

CODE REVIEW COSTS

Less than one percent of the annual budget, $125,000 annually or $1.25 million over the next 10 years, will be dedicated to the cost of code reviews. This cost is expected to increase in the coming years.

MAINTENANCE & REPAIR

As described in the Life-Cycle Planning section, the building program funds routine maintenance, preservation treatments, and repairs for buildings.

CDOT anticipates about $2.1 million annually, or $21 million over the next 10 years, will be set aside for controlled-and-deferred maintenance.

Figure A.1-7 *Examples of Planned Capital Improvement Projects*

Maintenance Building 12-Bay Vehicle-Storage Facility and Office Bay ($3.2 M)

Craig Maintenance Building Eight-Bay Vehicle-Storage Facility and Office Bay ($2.4 M)

REHABILITATION, RECONSTRUCTION AND REPLACEMENT

Significant reconstruction investments are planned for several facilities over the next 10 years, including major repair projects, construction of a lean-to or addition, and construction of wash bays. Should all planned capital-improvement projects be built and construction costs begin to stabilize, between fiscal years 2023 and 2025, 14 buildings will be reconstructed and two buildings rehabilitated. These structures would cover 86 pieces of essential equipment that were previously uncovered, eliminate 20 grade F buildings, and improve two grade C buildings to grade A. If fiscal years 2026 and 2027 are funded as planned, the potential exists to reconstruct and consolidate 13 grade F buildings with 11 reconstructed buildings. This also would cover an additional 58 pieces of essential equipment and decrease the overall inventory by two buildings.

PERFORMANCE GAP ANALYSIS

CDOT's AIMS model forecasts the performance of buildings annually, including any anticipated performance gaps. This analysis is based on asset condition, anticipated funding, the model's recommended investment strategies, and other inputs. The Department's ability to close performance gaps largely depends on receiving additional funding.

NEEDS AND PROJECTED CONDITION

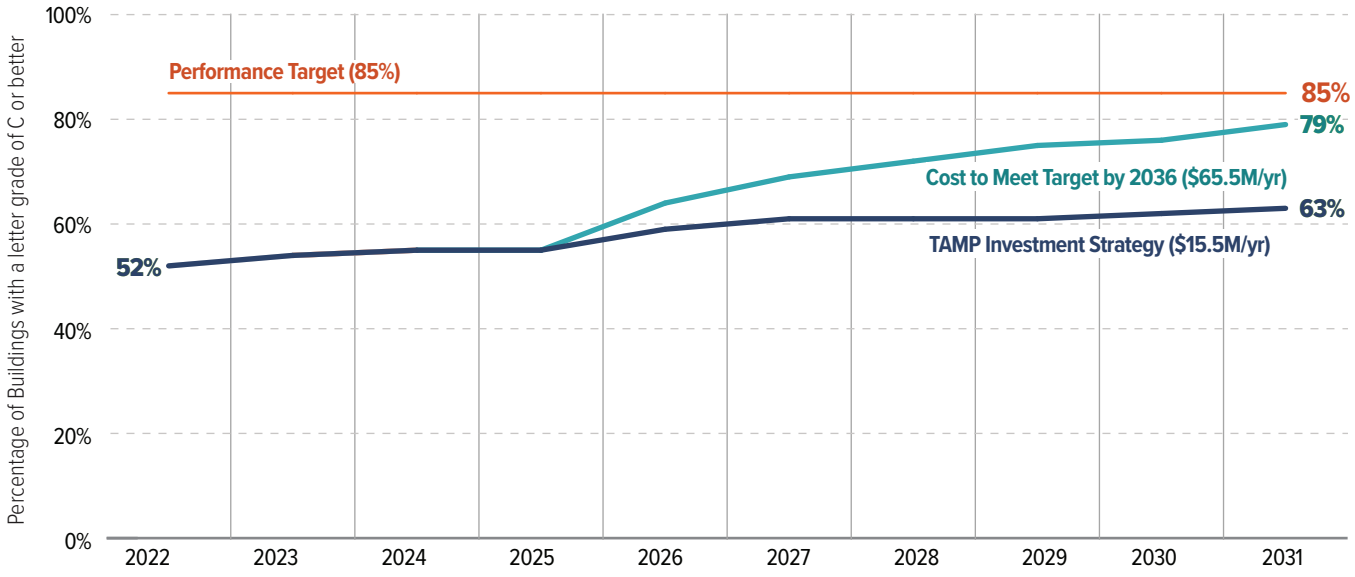
The AIMS model predicts the long-term performance of buildings given anticipated funding, as shown in the Financial Plan. Building ratings are deteriorated using deterioration models updated in 2021. Model inputs and outputs are reviewed by the Property Management Team on a regular basis. CDOT incorporates planned projects into the model assumptions, and the model recommends projects for periods with no planned projects.

Current funding levels, as contained in the Financial Plan, do not provide sufficient funding to meet the established PD 14.0 performance target for buildings. A significant increase in investment—more than $50 million annually—would be needed to meet the target by 2036.

Figure A.1-8 shows the expected percentage of buildings with a grade of C or better over time, under funding levels described in the Financial Plan. The model predicts an upward trend in condition after a dip in fiscal year 2025, but performance still falls short of the target condition.

Figure A.1-8 *Projection of Percentage of Buildings with a Grade of C or Better*

The anticipated annual budget of $15.5 million will not meet the performance target of ensuring that 85 percent of buildings have a C grade or better. The annual cost of meeting the target by 2036 (outside the TAMP timeframe), is more than $65.5 million, or an additional $50 million per year.



Most CDOT buildings were constructed during the initial development of the Interstate Highway System, in the mid-20th Century. In CDOT's inventory, the year of construction listed is often the year that CDOT acquired the building rather than the year it was built, meaning the building may be much older. Given the historical lack of consistent funding for the life-cycle management of buildings, the Buildings program's effort to bring its assets to a state of good repair has primarily taken a "worst-first" approach, focusing on structurally unsound buildings that are unsafe. This has resulted in a disproportionate number of replacement projects compared to more modest treatments.

The overall condition of buildings decreased in 2020 and 2021 due to a continuing shortfall in needed funding, as well as the more rigorous condition-rating methodology. Nevertheless, the projected trend toward improved conditions over the next 10 years is evidence that the approach is heading in the appropriate direction.

RISKS OF INSUFFICIENT FUNDING AND PERFORMANCE IMPACTS

Insufficient funding can result in reduced building functionality and impacts on operations. Potential outcomes are summarized in **Figure A.1-9**.

OPPORTUNITIES TO CLOSE THE GAP

CDOT is pursuing a range of strategies to ensure performance gaps are closed:

- **Addressing construction cost increases**—Continue to efficiently deliver existing projects. Continue to prioritize new projects that provide the highest return on investment.
- **Move to green buildings**—Prioritize green buildings with the highest benefit-cost ratio, to reduce operating costs and achieve environmental benefits/ outcomes. Seek alternative funding sources for these buildings where possible.
- **Labor cost increases**—Consider alternative delivery methods for economies of scale.

STRATEGIC USE OF ADDITIONAL REVENUE

Should CDOT receive additional revenue to fund the Buildings asset class, the Department's first priority is to eliminate any funding gaps related to achieving the PD 14.0 performance target. Once goals are achieved, the Department will reduce Poor backlog with a priority towards the most critical and/or vulnerable assets to improve system resilience. CDOT estimates the current "Poor" backlog for buildings could be eliminated with about $634 million.

Figure A.1-9 *Insufficient Funding Impacts on Building Functionality and Operations*

Without sufficient funding, CDOT may experience increased operational impacts like workplace injury and skilled employee turnover. CDOT may also experience a decrease in the functionality of buildings, such as decreased levels of service.

FUTURE IMPROVEMENTS

Intended asset-management improvements to the Buildings program address processes and technology.

PROCESS

Process improvement is a key aspect of maintaining and advancing the buildings asset-management program. The Buildings program will continue to refine the condition-rating scoring system to properly weight the categories and components of storage buildings, maintenance facilities, and vehicle-storage facilities.

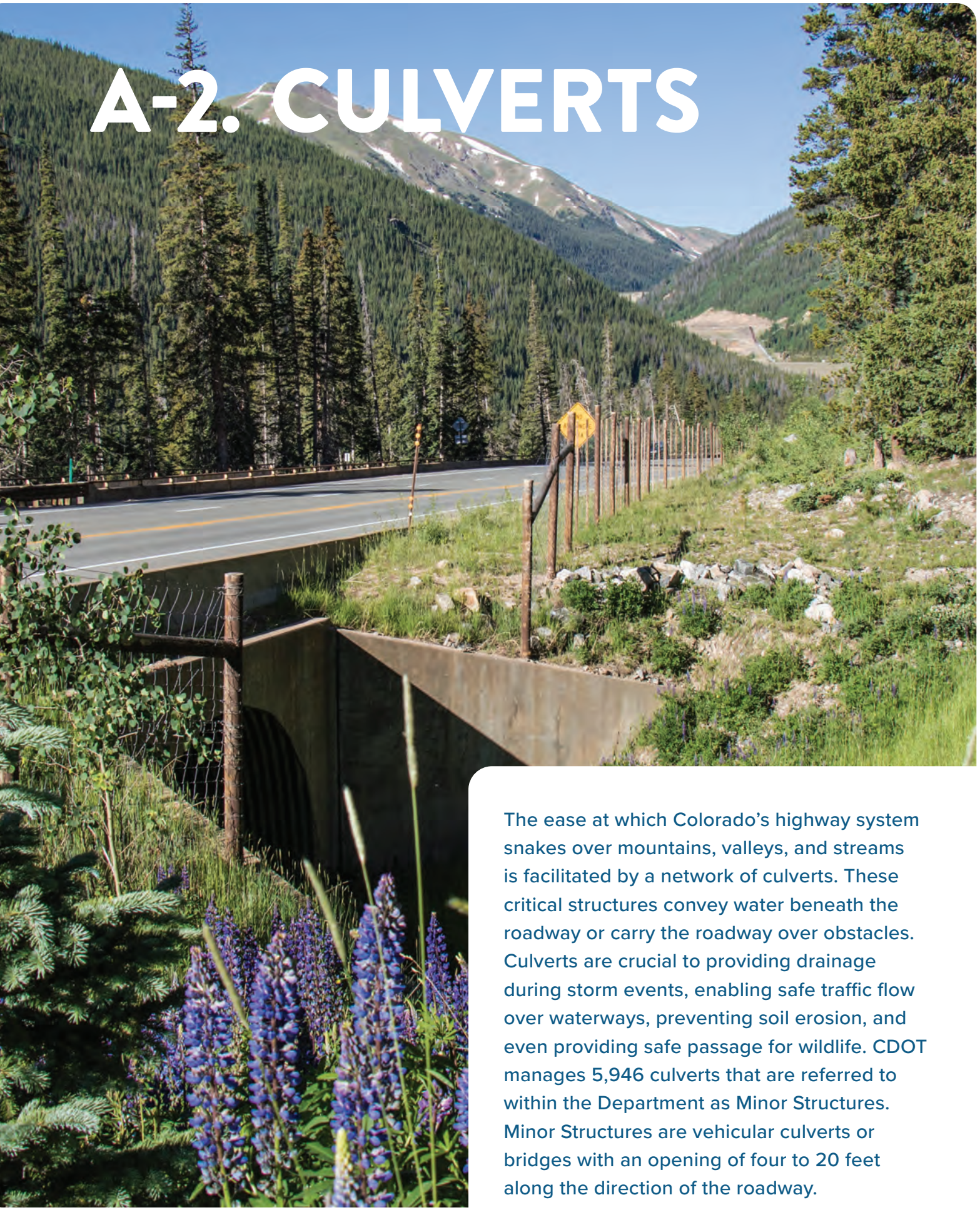
TECHNOLOGY AND ANALYSIS CAPABILITIES

Future process improvements would establish a stronger forecasting capability and integrate more robust asset-management practices. CDOT's AIMS model for buildings, which forecasts future conditions and recommends buildings projects, has recently been improved and optimized. It now has more treatment options to allow for more targeted investments and better forecasting. In particular, the model's treatment of vehicle-storage facilities has been improved and optimized to allow for treatment options beyond new construction. Staff is currently working to implement decision trees for offices to help maximize the benefit of a given budget.

The Buildings program also is undertaking a project with ESRI, the geographic-information system (GIS) software company, for storage of previous years' data. Currently, only the most recent assessment year's data is included in the program's dashboard. The build-out will include previous year's data to accurately show the deterioration of the buildings.

Ideally, the Buildings program would like to better link data in the SAP software and the dashboard to avoid the necessity of manual duplication of inventory records, although the program currently lacks the appropriate staff needed to undertake this effort.

A-2. CULVERTS



The ease at which Colorado's highway system snakes over mountains, valleys, and streams is facilitated by a network of culverts. These critical structures convey water beneath the roadway or carry the roadway over obstacles. Culverts are crucial to providing drainage during storm events, enabling safe traffic flow over waterways, preventing soil erosion, and even providing safe passage for wildlife. CDOT manages 5,946 culverts that are referred to within the Department as Minor Structures. Minor Structures are vehicular culverts or bridges with an opening of four to 20 feet along the direction of the roadway.

CDOT culverts are managed in alignment with the CDOT asset-management process described in the Introduction to the Asset Plan Appendix. Since 2019, conditions of the Culvert asset class have remained stable and have been close to achieving CDOT's performance target of 95 percent in Good or Fair condition. The current funding level is expected to sustain this level of performance for the next 10 years.

Figure A.2-1 *Culvert Assets at a Glance*

PERFORMANCE MANAGEMENT

The performance of culverts is monitored and managed as part of CDOT's performance management framework through a series of quantitative measures and an overall target for the asset class. This performance information helps guide funding decisions and tracks how well the assets are supporting the agency's strategic goals and transportation services.

POLICY DIRECTIVE 14.0 PERFORMANCE MEASURE

The asset management program for culverts (Culverts program) contributes to all Policy Directive 14.0 (PD 14.0) goal areas of asset management, safety, and mobility. Culverts provide a safe means of conveying water under a highway to avoid flooding or washout of the roadway. They ensure the orderly movement of traffic during rain and flood events by protecting roadways from being damaged or over-topped by water. Culverts reduce soil erosion as well as allow continuous water flows—enabling wildlife to move through these passageways safe from vehicle traffic. Culverts are designed to accommodate significant rain events, helping ensure that the highway system is resilient to extreme weather.

The specific performance measure in PD 14.0 for maintaining culverts in a state of good repair is the percentage of culverts in Poor condition. To determine culvert conditions, CDOT's culverts are inspected according to National Bridge Inspection Standards (NBIS) and receive Good, Fair, or Poor ratings.

The process for assessing condition through NBI standards is described in the Inventory and Condition section of this Asset Plan. **Table A.2-1** shows 2021 performance compared to the PD 14.0 target for culverts.

CDOT considers its culverts to be in a state of good repair, only if 5 percent or less are rated Poor. The current (2021) percentage of culverts in Poor condition is 5.4 percent, just short of the target of 5 percent. The reason for this gap is described in the Performance Gap Analysis section of this Asset Plan.

OTHER PERFORMANCE MEASURES

In addition to the condition ratings, CDOT identifies Essential Repair Findings during inspection. These findings indicate conditions or advanced deterioration of key elements that require action because they have affected the current capacity, serviceability, and anticipated service life of the culvert element or structure.

Table A.2-1 *CDOT Asset Management Metric and Performance Target for Culverts*

CULVERTS

Measure	Target	2021 Performance
Percent rated Poor	≤5%	5.4%

INVENTORY AND CONDITION

CDOT's culvert inventory and condition information is collected through the culvert inspection program, which is managed by the Bridge and Structure Inspection Unit within CDOT's Staff Bridge Branch. Consultant inspectors perform in-field inspections and enter inspection data into AASHTOWare's Bridge Management (BrM) database via an online enterprise user interface. The Bridge and Structures Asset Management Unit within Staff Bridge is responsible for data management and reporting of the inspection data. CDOT performs NBIS component-level inspections as well as element-level inspections on culverts.

INVENTORY

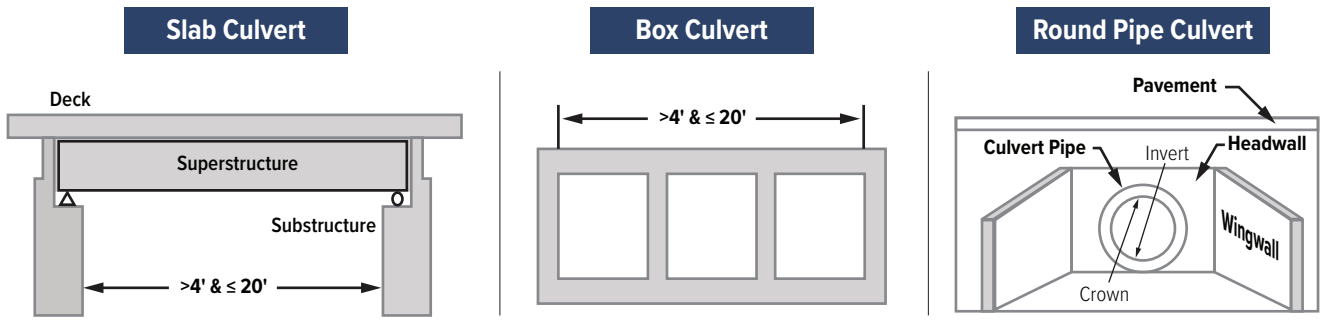
As of 2021, CDOT owns and maintains 5,946 culverts statewide, as presented in **Table A.2-2**. Culverts are constructed with different materials (e.g., concrete, steel, timber, etc.) and geometric shapes (e.g., box, arch, round, etc.) to take advantage of submergence and increase hydraulic capacity.

Figure A.2-2 shows schematic diagrams of different types of culverts, indicating how the total span is measured.

Table A.2-2 *Inventory of Culvert Assets*

Culvert Construction Type	Count
Corrugated Metal Pipe	2,864
Concrete Box Culvert	2,189
Reinforced Concrete Pipe Culvert	559
Precast Concrete Box Culvert	109
Arch Culvert	103
Timber Bridge	30
Other	92
Total	5,946

Figure A.2-2 *Examples of Culvert Assets*



Source: CDOT's 2021 State of the Assets Presentation

ASSET HIERARCHY

To understand the performance of culvert assets, CDOT tracks the condition and/or functionality of the major elements and other components that comprise each culvert. **Table A.2-3** provides an overview of the relationship between different types of culverts and the components and elements that comprise each type.

Table A.2-3 *Culverts Asset Hierarchy*

Design Type	NBIS Components	Typical Elements	Typical Materials
Pipe culvert	» Culvert	» Culvert (barrel) » Headwalls » Wingwalls	» Steel » Concrete » Plastic
Box culvert	» Culvert	» Culvert (barrel) » Headwalls » Wingwalls	» Concrete » Masonry
Minor Bridge—Girder and deck structure	» Deck » Superstructure » Substructure	» Deck » Girders (superstructure) » Piers, abutments, pier caps (substructure)	» Timber » Steel » Concrete
Multi-barrel	» Culvert	» Culvert (barrel) » Headwalls » Wingwalls	» Any combination of the above

CONDITION

CDOT's culvert inventory and condition information is collected through the Culverts program, which is managed by the Bridge and Structure Inspection Unit within the CDOT Staff Bridge Branch. Consultant inspectors perform inspections on culverts following the guidance outlined within the NBIS as defined in federal regulations (23 CFR 650 Subpart C). CDOT uses a four-year inspection frequency for culverts.

Inspectors rate the culvert's overall condition on a scale from 0 to 9. Culverts are categorized as in Good, Fair, or Poor condition based on the numeric rating, as presented in **Figure A.2-3**.

Figure A.2-3 *NBIS Rating Scale*

Inspectors perform component- and element-level inspections and enter inspection data into AASHTOWare's BrM database via an online enterprise user interface. Collected data includes an overall culvert rating (0–9), identification of condition states of individual elements, defects on a scale from 1–4, and location and ownership information. The Bridge and Structures Asset Management Unit within Staff Bridge is responsible for data management and reporting of the inspection data. The Staff Bridge Asset Management Engineer acts as asset manager for the Culverts program.

Creation of an Essential Repair Finding indicates conditions or advanced deterioration of key elements that has affected the current capacity, serviceability, and anticipated service life of the element or structure, requiring action to prolong the service life. Essential Repair Findings serve as the primary source for the culvert project-selection process. Approximately 100 new Essential Repair Findings are identified each year by Staff Bridge. ERF data is stored in spreadsheets on CDOT's network folders. Inspectors identify Essential Repair Findings and then issue Essential Repair Letters.

Typical findings that warrant an Essential Repair Finding notice include:

1. Perforations due to advanced corrosion in a corrugated metal pipe.
2. Deformation or movement of culvert pipe sections—concrete or steel.
3. Severe abrasion and deterioration of concrete.
4. Failed wingwalls and scour at the inlet or outlet of a culvert.
5. Silted-in culvert leading to a significant reduction of hydraulic capacity.

CONDITION TRENDS

Current conditions for CDOT's culverts are summarized in **Table A.2-4**. As of 2021, CDOT has 5,626 (94.6%) out of 5,946 culverts in Fair or Good condition. There are currently 374 open Essential Repair Findings identified on the State Highway System.

Since 2017, the percentage of culverts in Good condition has been steadily declining, while the percentage in Fair condition has been steadily increasing, and the percentage in Poor condition has remained relatively constant. Open Essential Repair Findings saw a steady increase from 2016-19. However, from 2019-2021, the number of open Essential Repair Findings remained almost constant.

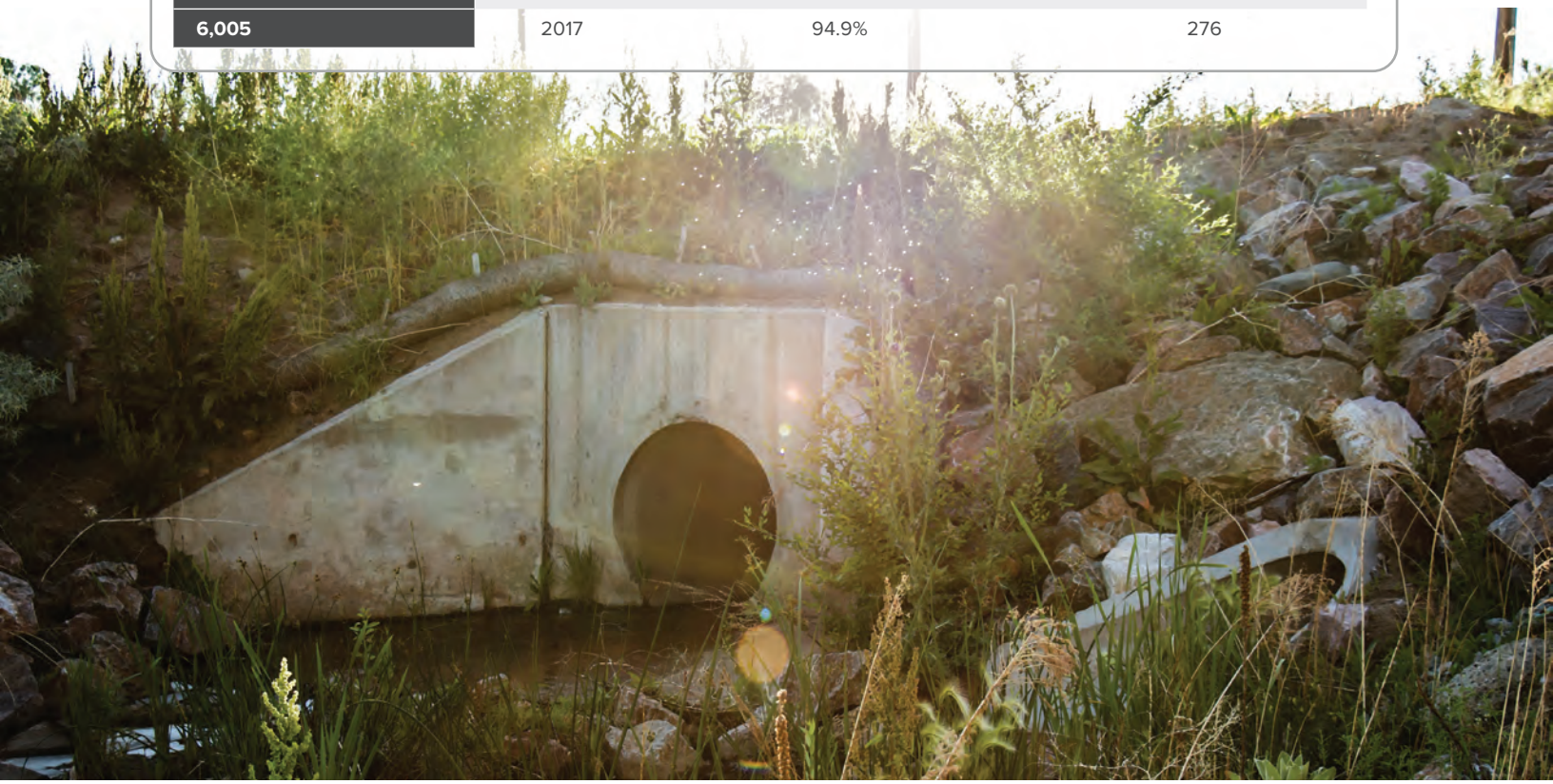
ASSET VALUE

CDOT undertook an assessment of asset value in 2022 for this document. The replacement value of culvert assets is determined by the culvert length multiplied by the unit cost (linear feet). This replacement value is $3.02 billion.

To calculate current asset value, the replacement value is discounted to consider the current condition of the asset and an obsolescence factor. The obsolescence factor considers the current age of a culvert and an obsolescence age of 70 years. The current value of culverts is $1.6 billion.

Table A.2-4 *Culvert Condition Trends*

Number of Culverts	Year	Percentage in Fair or Good Condition	Essential Repair Findings
5,946	2021	94.6%	374
5,937	2020	94.5%	375
5,956	2019	94.8%	375
5,989	2018	94.6%	347
6,005	2017	94.9%	276



LIFE-CYCLE PLANNING

CDOT analyzes its culvert inventory and inspection data to forecast investment needs and set work priorities. This process is known as life-cycle planning and accounts for the whole-life costs of planning, constructing, and maintaining culverts with consideration for minimizing long-term costs while preserving or improving the condition. CDOT performs major rehabilitation and reconstructions on culverts that have Essential Repair Findings or that are in Poor condition. Culverts in Good and Fair condition receive routine maintenance, as needed.

LIFE-CYCLE PLANNING

CDOT uses a condition-based approach to the life-cycle management of culverts. This means condition data is used to determine appropriate type and timing of work and to prioritize potential work within available budgets. CDOT performs cost-benefit analyses to determine the most cost-efficient treatment program and identify which culvert projects should be prioritized for maintenance.

The bulk of culvert life-cycle management consists of addressing culverts with Essential Repair Findings. This approach aims to reduce the backlog of culverts with Essential Repair Findings, thereby reducing the risk of culvert failure. The Culverts program is expected to include preservation strategies such as slip lining (i.e., lining existing pipe culverts with a smaller diameter pipe) once the backlog of Poor culverts is reduced to a manageable level. This level is defined as being when the number of Essential Repair Findings remedied is at or below the number of new Essential Repair Findings identified in the same year.

PROGRAM DECISION-MAKING

CDOT uses several different treatments to cost effectively address culvert deterioration. Culvert treatments can include activities such as slip-lining, reconstruction, or wingwall repair (e.g., concrete patching or resetting of a culvert wingwall) depending on the culvert condition and availability of funds. Culvert-treatment work types are defined as follows:

- **Preservation** includes cleaning, brush clearing, and similar treatments that help the culvert function properly.
- **Maintenance** includes scour repair and miscellaneous repairs. These treatments do not provide a change in culvert condition but do extend service life.
- **Rehabilitation** includes slip lining, spray lining (i.e., lining a deteriorated pipe with a layer of protective material such as grout), and other repair treatments. These treatments restore culvert condition and extend service life. To receive a slip lining, a culvert cannot have begun collapsing. This treatment is considered a preservation or rehabilitation action, depending on the condition of the existing pipe.
- **Reconstruction** consists of replacing the existing structure with a new structure. This results in a resetting of expectations regarding culvert condition and service life. Replacement is typically accomplished by excavating through the overlying pavement and placing a new structure, although new pipe installation methods that do not require digging an open trench may also be used. The most cost-effective approach is selected as part of the design process. Hydraulic analysis is required as part of the design process to make sure the final culvert is properly sized.
- **Initial Construction** consists of construction of a structure where no structure has ever been built.

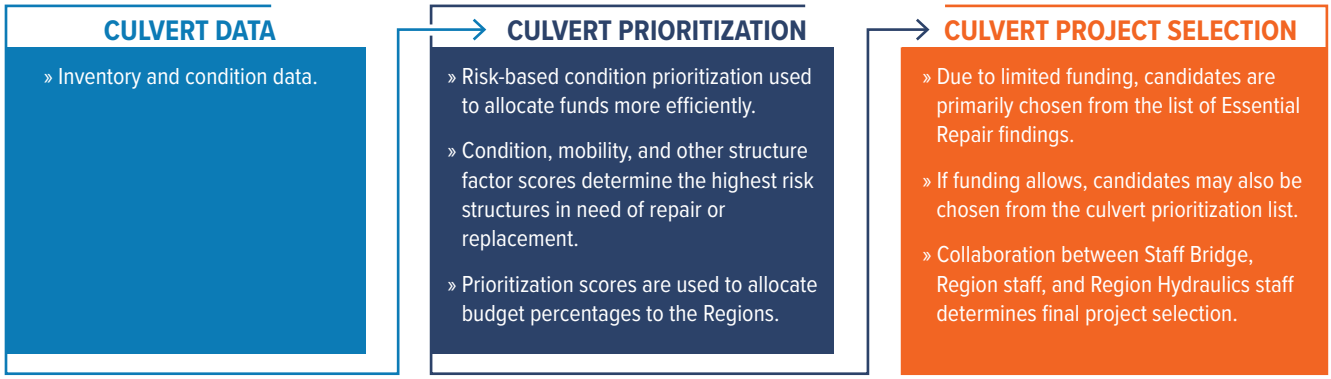
A list of culvert treatments and their approximate costs are shown in **Table A.2-5**.

Table A.2-5 *Culverts Life-Cycle Management Activities*

FHWA Work Type	Activity	Typical Cost
Preservation	Cleaning	<$2,000 per culvert
Maintenance	Inspection	<$2,000 per culvert
Rehabilitation	Slip line/Spray line	$700 per linear foot
Reconstruction (replacement)	Replacement of an existing structure	$4,300 per linear foot
Initial Construction	Construction of a structure where no structure has ever been built	Varies

The project-selection process for culverts (**Figure A.2-4**) is driven by culvert condition, with projects chosen primarily from the list of Essential Repair Findings. CDOT Regions are provided with the culvert-prioritization list annually and use the list to identify culvert projects for that year. Region staff attempt to bundle similar culvert treatments into single projects to improve efficiency where possible. Additionally, CDOT Regions' maintenance staff implement certain repairs such as cleaning, slip lining, or invert lining (i.e., lining of the culvert invert with protective material such as grout) as skills, time, and budget allows. Routine maintenance, preservation treatments, and repairs that do not require engineering are typically scheduled after notification of an Essential Repair Finding or if discovered during an in-field maintenance visit.

Figure A.2-4 *Culvert Prioritization and Project-Selection Process*



RISK MANAGEMENT

Aligned with CDOT's risk management approach, the Culverts program manages risk across multiple levels—agency, programmatic, and project/asset. Section 6 of the TAMP provides more information about CDOT's risk-management methodology and processes, including an explanation of elements comprising risk scores.

The Culverts program maintains a register of risks to its overall program and projects. The top risks are presented in **Table A.2-6.**

Table A.2-6 *Top Culverts Risks*

Risk Level	Threat/ Opportunity	Risk Score[1]	Risk-Management Strategy
Project	Roadway washout from pipe failure.	51.8 (T)4 x (C)4.3 x (V)3	Treat—Inspections; identify "essential repairs" and add to critical-culverts list.
Project	Roadway settlement due to hydraulic piping/overtopping.	36 (T)3 x (C)3 x (V)4	Treat—Culvert replacement or an additional culvert to increase capacity.
Project	Culverts less than 48-inch diameter failing and closing road—not managed currently.	28.8 (T)3 x (C)3.2 x (V)3	Treat—Systematic inventory, clean, inspect, and repair.

1 Risk Score = Threat Likelihood (T) * Total Consequence and Consideration Score (C) * Vulnerability (V)

FINANCIAL PLAN

CDOT sets planning budgets for its asset programs four years in advance. The plan below assumes that funding for the Culverts program will remain static for the foreseeable future, at the level most recently set ($8.2 million for fiscal year 2025). These budget assumptions, combined with CDOT's life-cycle management approaches discussed in the subsequent section, inform the investment strategies for culverts that CDOT plans to leverage to achieve system-wide asset performance goals while minimizing life-cycle costs.

FUNDING SOURCES

The culverts portion of the Transportation Asset Management (TAM) program supports the life-cycle management for culvert assets. Of the allocated funding, approximately $1 million per year is used for inspections. Meanwhile, preservation and maintenance provided by the Maintenance Levels of Service (MLOS) program is budgeted separately, in the MLOS Financial Plan.

PLANNED FUNDING

Table A.2-7 summarizes the projected funding levels for the Culverts program for fiscal years 2022-31.

Table A.2-7 *Financial Plan for Culvert Assets (in Millions)*

FY22	FY23	FY24	FY25	FY26	FY27	FY28	FY29	FY30	FY31
$8.6	$8.3	$8.2	$8.2	$8.2	$8.2	$8.2	$8.2	$8.2	$8.2

INVESTMENT STRATEGIES

CDOT forms investment strategies based on its financial plan and life-cycle management strategies to achieve system-wide asset performance goals while minimizing life-cycle costs. The investment strategies delineate different types of work to be performed across CDOT's culvert assets over a 10-year period.

BACKGROUND: DETERMINING INVESTMENT STRATEGIES

The Department's investment strategies are informed by the AIMS asset model. Each year, the current culvert inventory and condition data are loaded into AIMS, and the model forecasts culvert conditions over the following 20-year period. AIMS also generates a list of alternative strategies for each culvert. The strategies include repair, rehabilitation, and replacement treatments based on business rules created by CDOT in the form of decision trees. The AIMS optimization function generates a set of strategies that maximizes the benefit for any given budget.

PLANNED INVESTMENTS

MAINTENANCE AND REPAIR

CDOT's maintenance crews conduct culvert maintenance activities that do not require engineering, including routine maintenance, preservation treatments, and repairs. Activities that do not require engineering are part of the MLOS asset plan including the MLOS financial plan and investment strategies.

REHABILITATION, RECONSTRUCTION, AND REPLACEMENT

CDOT's Culverts program performs routine inspection, repair, rehabilitation, reconstruction, and replacement of culverts that are not covered under the MLOS program.

PERFORMANCE GAP ANALYSIS

CDOT uses its AIMS model to forecast the performance of its culvert assets and any anticipated performance gaps annually. The results of this analysis inform the financial plan and investment strategies. Based on the most recent analysis, current funding will allow CDOT to remain close to achieving its performance target for culverts.

NEEDS AND PROJECTED CONDITION

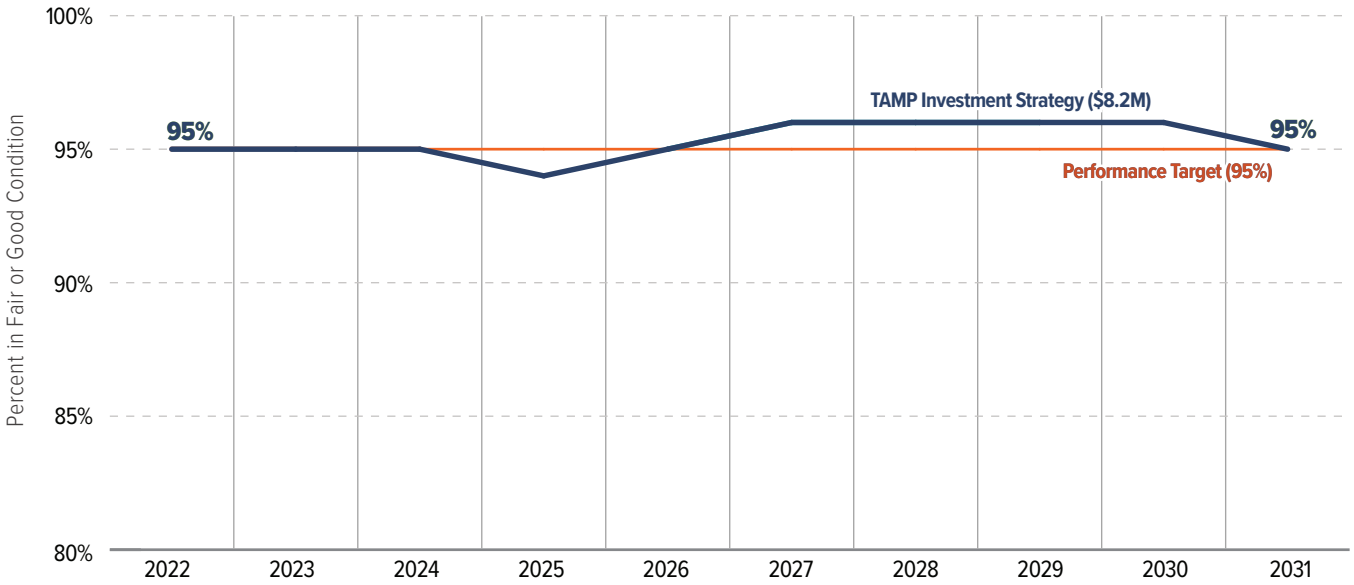
CDOT's AIMS model predicts the long-term performance of culvert assets, constrained by anticipated annual budgets.

The model's forecast currently relies on deterioration assumptions developed in 2016. Additionally, CDOT has programmed the model to assume that budgets in the first few years of the forecast are spent on a planned list of actual, upcoming culvert projects ("committed projects"). In subsequent years of the forecast, the model begins "spending" the budgets on projects selected by the model itself.

The model's forecast is based on the culvert Financial Plan, which dedicates about $8.2 million per year to the Culverts program. This funding level provides sufficient funding to meet the PD 14.0 performance target until 2031, as shown in **Figure A.2-5**. To meet the target for the 10-years after 2031 requires an additional investment of $2 million per year.

Figure A.2-5 *Projection of Culvert Assets Performance*

The anticipated annual budget of $8.2 million will enable CDOT to meet the performance target of ensuring that 95 percent of culverts are in Good or Fair condition.



IMPACTS OF INSUFFICIENT FUNDING

Culverts are crucial to the resiliency of CDOT's highway system. As a result of insufficient funding, the following risks will increase:

- **Safety and Mobility:** During rain and flood events, the drainage of the roadway will be poor and culvert failures are possible. This would result in highway closures, blocked access for commerce/emergency services, increased damage to pavements, and threats to public safety.
- **Financial:** Delays in performing repair or rehabilitation of culverts lead to greater funding needs in the future.

OPPORTUNITIES TO CLOSE THE GAP

CDOT regularly evaluates asset investment strategies and funding levels, including a review of analyses from the AIMS model to determine the best strategies to meet condition targets. The Department may alter its existing strategy by adjusting treatments, condition targets, and other factors to help close performance gaps when they exist. In addition, examples of recent efficiencies that may help close gaps include:

- **Statewide Preventive Repair Prioritization:** This effort prioritized all culverts with open Essential Repair Findings that are good candidates for slip-lining or spray-lining treatments. The effort included preliminary hydraulic information to further verify highest priority candidates.
- **Concrete Mat Invert Lining:** This new, cost-effective treatment enables repairs during early phases of culvert deterioration.

STRATEGIC USE OF ADDITIONAL REVENUE

Should CDOT receive additional revenue to fund the Culverts asset class, the Department's first priority is to eliminate any funding gaps related to achieving the PD 14.0 performance target. Once goals are achieved, the Department will reduce Poor backlog with a priority towards the most critical and/or vulnerable assets to improve system resilience. CDOT estimates the current "Poor" backlog for culverts could be eliminated with about $130 million.

FUTURE IMPROVEMENTS

Improvements to the Culverts program will address processes and technology.

PROCESS

Process improvement is a key aspect of maintaining and enhancing the Culverts program. CDOT intends to improve the capture of accurate inventory data and improve its ability to track the condition and disposition of culverts over time.

Other improvements include:

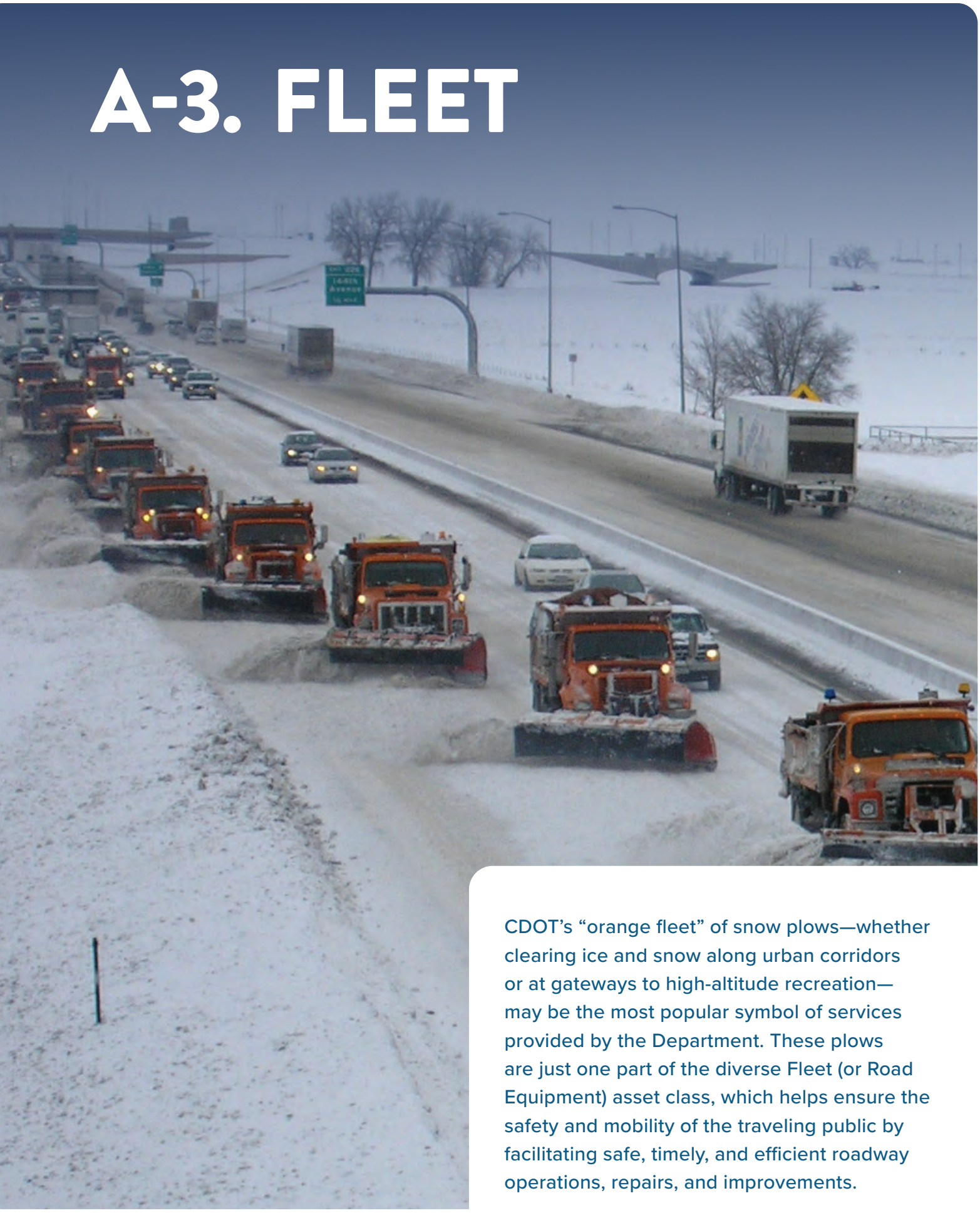
- Increase efforts to bundle culvert treatments with Bridge and Surface Treatment projects to reduce culvert treatment costs through economy of scale.
- Implementing rehabilitation techniques to extend the service lives of culverts in fair or poor condition, thereby delaying the need for costly replacements.
- Continuing to improve the coordination between culvert asset management and resilience efforts to reduce the likelihood of overtopping or washouts during extreme weather events.

TECHNOLOGY AND ANALYSIS CAPABILITIES

As CDOT's culvert-management efforts mature, the Department will pursue ongoing improvements such as:

- Similar to Bridges, SIMSA will incorporate culvert assets and will:
  - Consolidate culvert data (e.g., condition, inventory) for easy access and use throughout the Department, including serving as a platform to upload and access “as-built” plans.
  - Streamline culvert inspection and inventory data collection and review for more accurate, up-to-date information.
  - Integrate with CDOT’s AIMS model so that data uploads (e.g., new condition and inventory data) to the model are easier than in the past.
- Enhancing condition and performance-forecasting capabilities with improved performance models. The collaboration between UC Denver and CDOT to develop deterioration models using machine learning will include culvert deterioration models as well.

A-3. FLEET



CDOT's "orange fleet" of snow plows—whether clearing ice and snow along urban corridors or at gateways to high-altitude recreation—may be the most popular symbol of services provided by the Department. These plows are just one part of the diverse Fleet (or Road Equipment) asset class, which helps ensure the safety and mobility of the traveling public by facilitating safe, timely, and efficient roadway operations, repairs, and improvements.

CDOT employs a comprehensive asset-management process for the Fleet program that is closely aligned with the process described in the Introduction to the Asset Plan Appendix.

CDOT's large fleet of vehicles is managed by Fleet Services in CDOT's Division of Maintenance and Operations. These heavy-duty vehicles range in size and function from one-ton patrol vehicles to the snowplow trucks. The fleet allows CDOT to perform such functions as:

- Basic road construction
- Road maintenance, such as snow plowing and removal
- Operations

The purchase prices of heavy-duty vehicles continue to rise significantly. The state's transition to electric vehicles—already mandated for Colorado's light duty fleet—will contribute to additional rising costs.

As of April 2021, there were 3,219 units of rolling stock, not including attachments such as plows. Fleet assets can be categorized into four use categories:

- Essential (snowplow trucks and snow removal trucks)
- Road (utility trucks, and attenuators)
- Off-Road (graders and loaders)
- Support (trailers and air compressors)

Light-duty vehicles, such as pickup trucks, are leased through State Fleet Management, Division of Capital Assets, in the State's Department of Personnel and Administration, and are not included in this plan.

Figure A.3-1 *Fleet Assets at a Glance*

PERFORMANCE MANAGEMENT

The performance of fleet assets is monitored and managed primarily by evaluating the percentage of each vehicle's "useful life" that has been expended. Additional performance measures, including percent life age, percent life usage, and maintenance costs, are also used to prioritize replacements.

POLICY DIRECTIVE 14.0 PERFORMANCE MEASURE

The asset-management program for fleet contributes to CDOT's Policy Directive 14.0 (PD 14.0) strategic goal areas—safety, asset management, and mobility. Fleet assets are critical for providing the necessary equipment to perform basic traffic and maintenance functions safely and efficiently. Fleet assets enhance mobility throughout the state by providing critical equipment needed to complete road improvements and reopen closed roads. CDOT plows over six million lane miles each year to keep roads navigable.

The performance measure in PD 14.0 for judging the state of good repair of fleet assets is the average percentage of "useful life" expended. Useful life, which is specific to each vehicle and equipment type, is defined as the length of time that a vehicle or piece of equipment is expected to provide CDOT with adequate performance. The percentage of "useful life expended" is calculated by averaging the asset's age as a percent of the typical replacement age, and the asset's usage as a percentage of expected lifetime usage. A value of 100 percent indicates that a piece of equipment has reached its full useful life. Values greater than 100 percent indicate that a vehicle or piece of equipment has exceeded its useful life. PD 14.0 sets the asset-management target for fleet assets as maintaining the average percentage of useful life expended of fleet assets at or below 75 percent. This is considered to be the level at which fleet assets are in a state of good repair.

Table A.3-1 shows the PD 14.0 target and 2021 performance for fleet assets.

OTHER PERFORMANCE MEASURES

MEASURES TO PRIORITIZE REPLACEMENTS

Additional performance measures are used to prioritize replacements. These include:

- **Percent life age:** Each asset has an expected life in terms of age. By aging the asset each year and comparing the current age against the typical replacement age, the Percent Life Age is calculated.
- **Percent life usage:** Each asset has an expected usage life in terms of total mileage or total hours of use. By comparing the annual hours or mileage used against the manufacturer's life expectancy, the Percent Life Use is calculated.

Table A.3-1 *Performance Metric and Target for Fleet Assets*

FLEET

Measure	Target	2021 Performance
Average percentage of useful life expended	75% or less	69%

Additionally, the average five-year maintenance cost for each asset is tracked and used in conjunction with the other performance measures to determine replacement eligibility.

ACCELERATED REPLACEMENT WITH ALTERNATIVE-FUEL VEHICLES

Colorado's Executive Order D 2015-013 directs the state's Greening Government Leadership Council to work with all executive state agencies and departments to reduce weather-normalized energy consumption by at least two percent annually. This includes goals and directives to reduce petroleum used by the state's various fleets. To achieve these goals, CDOT participates as a member of the State Fleet Sub-Council, a body charged with helping to:

- Develop standard procedures and formulas for modeling and monitoring potential alternative-fuel vehicles and fuel reduction efforts that link acquisition and operations budgets.
- Create a process that allows fleet coordinators to replace vehicles before standard retirement age with alternative fuel vehicles if replacement is cost-effective.
- Evaluate alternative-financing options for vehicles, including leasing, energy-performance contracting, and other options that reduce costs.
- Establish policies and procedures that promote the use of non-petroleum-fueled vehicles and fleet efficiencies, striving for the use of non-gasoline and non-diesel fuels for a minimum of 90 percent of the time, when cost-effective.

INVENTORY AND CONDITION

CDOT owns and maintains 3,219 units of rolling-stock[1] fleet assets that are divided into four categories: Essential, Road, Off-Road, and Support. CDOT tracks these fleet assets within the SAP Equipment Database, which includes data on age, utilization, and cost of maintenance. These data are used to determine each asset's condition.

INVENTORY

Of the 3,219 vehicles in the fleet, 978 are classified as Essential vehicles, critical for important missions. These include snowplow trucks and other snow-removal vehicles (e.g., snowcats and snow blowers), as well as aerial-lift trucks for signal maintenance. The fleet asset inventory is provided in **Table A.3-2**.

Table A.3-2 *Current Inventory and Condition of Fleet Assets*

Asset Type	Current Count	Useful Life (Years)	Average Age (Years)	Average Percent Age
ESSENTIAL	*978*	*15*	*12.00*	*80%*
Snowplow Trucks	868	12	12.00	100%
Snowcats	5	15	10.4	70%
Others	105	15	9.1	60%
ROAD	*1069*	*10*	*10.08*	*108%*
One-Ton Trucks	377	10	9.6	96%
Mechanic Trucks	69	10	11.1	111%
Others	623	10	11.6	116%
OFF-ROAD	*667*	*15*	*12.92*	*86%*
Dozers	10	15	13.1	87%
Motor Graders	85	12	15.9	133%
Loaders	263	15	13.7	91%
Others	309	15	11.4	76%
FLEET SUPPORT	*505*	*15*	*9.99*	*66%*
Personnel Lifts (Scissor Lifts)	5	10	14.2	142%
Large Welders	8	15	20.5	137%
Others	492	15	9.7	65%
Total	3219	13.2	12.23	93%

1 This number changes weekly, based on fleet turns and up-fit schedule.

CONDITION

The condition of fleet assets is measured by the average Percent Life. The Percent Life is based on the following factors:

Percent Life Age = Vehicle age (years) / Vehicle expected life (years)

Percent Life Usage = Vehicle actual usage (miles or hours) / Vehicle expected life usage (miles or hours)

The Percent Life is calculated by averaging the Percent Life Age and the Percent Life Use, with an additive factor based on the age of the equipment as follows:

- If Percent Life Age ≥ 200, then 50 points are added.
- If Percent Life Age ≥ 180, then 40 points are added.
- If Percent Life Age ≥ 160, then 30 points are added.
- If Percent Life Age ≥ 140, then 20 points are added.
- If Percent Life Age ≥ 120, then 10 points are added.

While the overall fleet is meeting the PD 14.0 target, equipment can still pose concerns. Indeed, certain vehicles are approaching or exceeding twice their expected useful life.

Vehicle and equipment age, usage (mileage), and maintenance costs are maintained in the fleet-asset database, which resides in CDOT's financial system (SAP). These data are imported into CDOT's Asset Investment Management System (AIMS) model to calculate condition.

For 2021, 68.7 percent of the useful life of the fleet had been expended. This is within the target of 75 percent or less. The condition of CDOT's fleet has slightly improved in recent years, from about 73 percent useful life expended in 2017, to about 69 percent in 2021.

ASSET VALUE

CDOT undertook an assessment of asset value in 2022. The current replacement value of fleet assets is determined by considering the acquisition value and inflation. This replacement value is $452 million.

To calculate current asset value, the replacement value is discounted by the useful life, which is based on the average age of all fleet assets, plus two standard deviations of age. The current value of fleet assets is $270 million.

LIFE-CYCLE PLANNING

The life-cycle management of fleet assets considers preservation, routine maintenance, rehabilitation and replacement.

FACTORS INFLUENCING FLEET PERFORMANCE

The lifespan of fleet assets is primarily based on age. As vehicles and equipment get older, performance and reliability decrease, putting them at risk of failure. As maintenance costs increase over time, it eventually becomes more cost-efficient to replace an asset rather than continue to repair it. The lifespan of fleet assets is also usage-based. Assets that are overused can expend their useful life quicker than assets used more conservatively. CDOT uses a combination of age and usage to determine eligibility for treatments. Different types of fleet assets will have different life spans because of these factors.

FLEET LIFE-CYCLE MANAGEMENT APPROACH

Fleet Services tracks vehicle and equipment age, utilization, and the cost of ownership and maintenance. It then stores these data in its SAP Equipment Database. Longer-term life-cycle decisions are supported by CDOT's Asset Investment Management System (AIMS) model. The model uses the data in the SAP system, along with deterioration curves based on manufacturers' recommendations and CDOT experience, as well as CDOT replacement criteria, to develop a recommended replacement list.

While the fleet asset-management program is focused exclusively on replacing heavy-fleet vehicles, Fleet Services also manages:

- The maintenance and repair of the heavy fleet, including in-house repairs performed and funded through the Maintenance Levels of Service (MLOS) program. Fleet Services also manages outside repairs and setting specifications and scopes-of-work for purchasing repair services.
- Fuel cards for CDOT employees to purchase fuel commercially or from CDOT's bulk-fuel tanks.
- Purchasing bulk-fuel tanks for CDOT vehicles.
- Purchasing new heavy-fleet equipment.
- Requests for new light-fleet vehicles, which are funded through the State's Department of Personnel and Administration.

Fleet Services also manages light-fleet vehicles.

FLEET PROGRAM DECISION MAKING

TREATMENT SELECTION

The process for selecting treatments begins each year when vehicle and equipment age, usage (mileage), and maintenance costs are imported from the SAP system into the AIMS model to calculate needs. The only treatment type used by the model for fleet assets is vehicle replacement. The model generates specific replacement recommendations for each vehicle in the fleet, based on its expected life in terms of age and usage.

The model's analysis assumes that regular base maintenance or preservation activities are conducted per prescribed regimens. It does not account for such rehabilitation activities as replacement transmissions or new truck decks. While such activities are known to significantly extend vehicle life, the extent and schedule of such interventions is not sufficiently documented in a form that can be usefully inputted into the model.

Equipment usage is measured in terms of hours of use or miles driven. The percentage of useful life expended is calculated as the current readings (hours/miles) divided by the expected hours/miles at replacement. The performance measure used in the AIMS model is the "percentage of useful life

expended, dollar-weighted" which multiplies the percentage of life of the equipment that's been expended by the replacement cost. Equipment replacement is generally triggered when the percentage of useful life expended exceeds 120 percent.

FLEET MANAGEMENT WORK TYPES

Preservation, Maintenance and Rehabilitation

Vehicles and equipment are assigned to Regional maintenance sections, but some loaning of equipment is done when required. For day-to-day vehicle maintenance, Fleet Services abides by the Federal Motor Carrier Safety Regulation (FMCSR). Through FMCSR Procedural Directive 9.2 and the Heavy Fleet Protocol, it is also required that Fleet Services perform routine maintenance. The Fleet Asset Manager develops the standards, which are then incorporated into CDOT protocol or policy and procedural directives. Preventive-maintenance work orders are monitored to ensure that they are completed. Operators check vehicles daily, and mechanics carry out annual safety inspections.

These activities are undertaken by the Maintenance Levels of Service (MLOS) program. Definitions for these items are included in **Table A.3-3**.

Reconstruction (Replacement)

CDOT replacement criteria are used to determine the optimum time to replace fleet equipment. CDOT wants to ensure that it is not maintaining equipment that has a high cost of maintenance compared to its replacement cost. The Department has found that vehicles and equipment can often reach 120 percent of expected useful life before reaching that threshold. CDOT uses the age and usage performance measures described in Section 3 ("Performance Management"), along with five-year maintenance costs, to evaluate if each vehicle or piece of equipment is eligible for replacement:

- If percent life age is <=60 percent and the five-year average maintenance cost is > 25 percent of equipment replacement cost, the asset is eligible for replacement.
- If percent life age is <=120 percent and the five-year average maintenance cost is >30 percent of the replacement cost, then the asset is eligible for replacement.
- If the percent life is >=120 percent or the percent life age is >120 percent, then the asset is eligible for replacement.

Once the AIMS model generates a replacement list, Fleet Services decision makers consult with stakeholders within CDOT's Regions/sections to ensure operational needs are met. Sections can recommend adjustments. The Fleet Manager presents the adjusted replacement plan to the Director of Highway Maintenance for final approval.

Vehicle replacement is becoming increasingly challenging as the cost of vehicles rises. For example, inflationary costs of steel and labor have driven the cost of snowplows up 27 percent in the past year. In addition, existing state policy and the State Clean Truck Strategy now being developed are likely to reduce the number of vehicles that can be replaced within existing budgets by nearly half for several vehicle types. For example, battery-electric street sweepers are nearly twice as expensive as fossil fuel-powered street sweepers.

Besides planned cyclical replacements, the escalating cost of vehicles affects the ability to replace vehicles severely damaged in accidents. The fleet experiences an average of 200 accidents each year, with a budget impact of some $1.5 million annually.

Expansion

The need for additional vehicles or equipment can be driven by government objectives and mandates, as well as by requests from CDOT Regions and sections. For example, CDOT's Policy Directive 1502.1, Traffic Control for Planned and Unplanned Work, mandates that Fleet Services must supply Class 6 traffic-control trucks with truck-mounted attenuators for maintenance patrols.

Additionally, a Region or division may request an additional type of new vehicle or equipment or an increase in the number of existing pieces of equipment. A written request containing a justification, such as employee safety, is submitted by the Region or division to the Fleet Manager and must be approved by the Director of Highway Maintenance and CDOT's Executive Director.

CDOT's asset-management treatments for fleet are aligned with FHWA work types in **Table A.3.3**. The FHWA category of "initial construction" is not applicable to vehicles and equipment and has been replaced in the table by "expansion." For the same reason, a "replacement" work type is used in the table instead of the FHWA "reconstruction" work type.

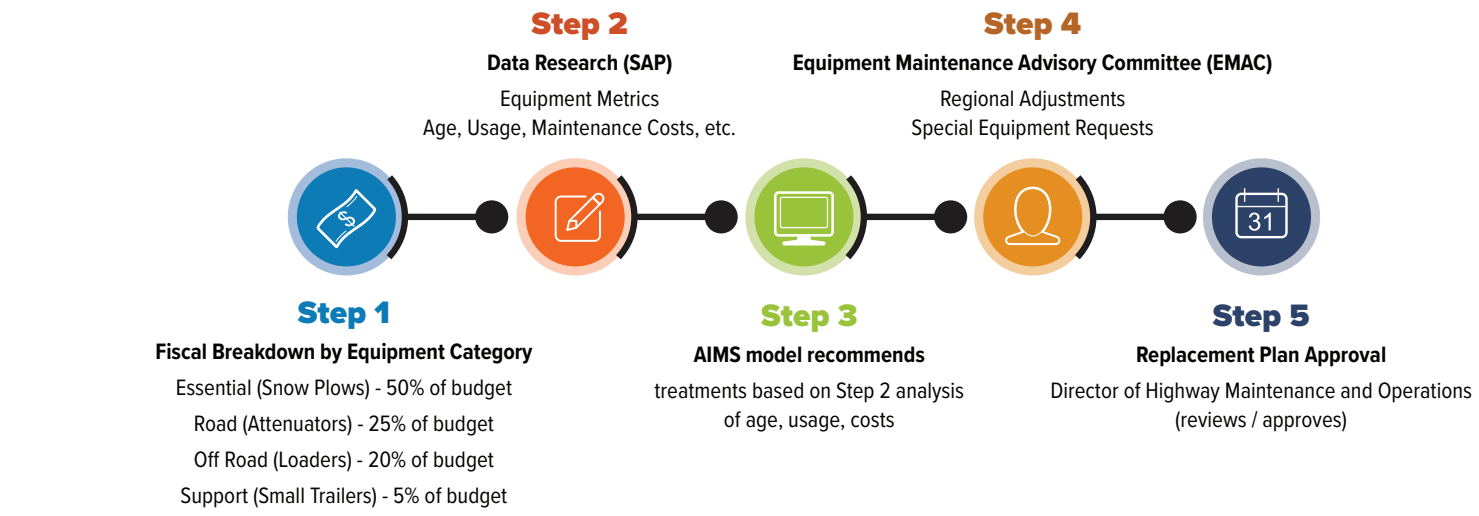
Table A.3-3 *Fleet Life-Cycle Management Activities*

Work Type	CDOT Activities
Preservation	Cleaning of equipment, performed by sections using operating funds.
Maintenance	Consists of oil changes, lube jobs, and minor and major repairs.
Rehabilitation	Consists of replacing rusted, cracked frame rails; removing excess rust and rebuilding truck beds; and repainting.
Replacement	Purchase of replacement vehicles or equipment.
Expansion	Purchasing additional or new vehicles.

PROJECT SELECTION AND DELIVERY

The project-selection process for fleet replacements is described and shown in **Figure A.3-2**.

Figure A.3-2 *Vehicle-Replacement Process*



RISK MANAGEMENT

CDOT maintains an ongoing register of risks for fleet assets at the agency, program, and project levels. Section 6 of the TAMP provides more information about CDOT's risk-management methodology and processes, including an explanation of elements comprising risk scores.

The Fleet program maintains a register of risks to its overall program and projects. Top risks are shown in **Table A.3-4**.

Table A.3-4 *Top Fleet Program Risks*

Risk Level	Threat/ Opportunity	Risk Score[2]	Risk Management Strategy
Project	Impacts/crashes of traffic with fleet vehicles	58.7 (T)4 x (C)4.9 x (V)3	Well-lit vehicles, driver awareness, lessons learned
Project	Lack of parts availability (partly due to age and obsolescence) limiting number of vehicles in use	33 (T)5 x (C)3.3 x (V)2	More budget to allow for this

FINANCIAL PLAN

This asset plan shows planned funding for fleet assets from 2022-31. For the first four years of this period, official planning budgets have been adopted by the Transportation Commission. For fiscal year 2026 and beyond, annual budgets in this plan are held at fiscal 2025 levels.

FUNDING SOURCES

The budget for the Fleet program, which funds fleet replacements, is a portion of the overall Transportation Asset Management (TAM) program budget at CDOT. Vehicle maintenance is funded outside of the Fleet asset program, as part of the Maintenance Levels of Service (MLOS) program budget, and is included within the MLOS Financial Plan. Occasionally, but inconsistently, these sources may be supplemented by the proceeds from the auction of vehicles retired from the fleet.

PLANNED FUNDING

The 10-Year Financial Plan for the Fleet program is shown in **Table A.3-5**.

Table A.3-5 *Financial Plan for Fleet Assets (in Millions)*

FY22	FY23	FY24	FY25	FY26	FY27	FY28	FY29	FY30	FY31
$22.0	$21.5	$21.5	$21.0	$21.0	$21.0	$21.0	$21.0	$21.0	$21.0

2 Risk Score = Threat Likelihood (T) * Total Consequence and Consideration Score (C) * Vulnerability (V)

INVESTMENT STRATEGIES

CDOT allocates a percentage of the total Fleet program budget to categories of equipment (i.e., Essential, Road, Off-Road, Support) based on priorities determined by the Director of Highway Maintenance. The AIMS model then generates a recommended-replacement list, based on the budget available to each category. This helps ensure that the model's recommendations support CDOT's objectives, not just identify and replace the greatest number of eligible assets.

BACKGROUND: DETERMINING INVESTMENT STRATEGIES

Each year the current fleet inventory and condition data are loaded into the AIMS model, and the model forecasts fleet performance under various budget scenarios. When the model's optimization process is complete, the model returns a recommended set of vehicles to be replaced by year (i.e., the fleet project list).

Purchasing additional vehicles (as opposed to replacing existing vehicles) is not evaluated in the AIMS model. Additions are evaluated based upon needs, such as the increase in maintenance that will be required due to adding additional lane miles to the highway network. MLOS Sections identify such needs and submit requests to the Director of Maintenance and Operations (DMO). The DMO and fleet asset manager evaluate the need and, if found satisfactory, a request is presented to the Transportation Commission for additional funds. There is no ongoing annual budget for fleet additions. Budget is requested as needed from the Transportation Commission, per Procedure Directive 9.2.

PLANNED FLEET INVESTMENTS

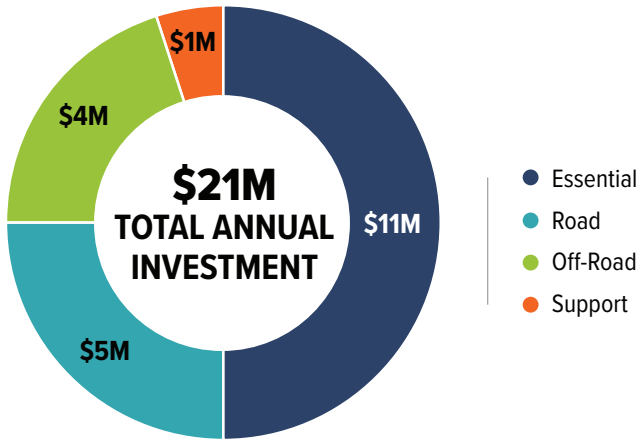
Preservation, Maintenance and Rehabilitation

These investments are the responsibility of the Maintenance Levels of Service (MLOS) Program.

Asset Management Replacements

When it comes to replacing fleet, CDOT expects to continue spending about 50 percent of annual fleet funding on the Essential vehicles category; about 25 percent on the Road vehicles category; 20 percent on the Off-Road fleet, and 5 percent on Support vehicles and equipment. (Refer to **Table A.3-2** for examples of each category.) Approximate investments by vehicle category are shown in **Figure A.3-3**.

Figure A.3-3 *Annual Investment by Fleet Category*



Additional Near-Term Investments

- **Replacement of Fire Trucks at Key Tunnels**
  The Transportation Commission allocated $800,000 in additional funds to replace fire trucks at the Hanging Lakes Tunnel and Eisenhower and Johnson Memorial Tunnels in advance of the regular replacement cycle.
- **Traffic-Control Trucks with Attenuators**
  As noted earlier, Policy Directive 1502.1 mandates that each patrol must have one Class 6 traffic-control truck with a truck-mounted attenuator. CDOT is working to procure enough of these vehicles to meet this directive. Because 70 additional truck-mounted attenuators are needed and no additional funding was provided, a timeline for purchasing these vehicles has not been established yet.
- **Low- or Zero-Emission Vehicles**
  To reduce the environmental footprint of the fleet, new efficient vehicles are continuously incorporated. This includes a first-of-its-kind, plug-in battery-powered system for bucket trucks that meets the fleet's operational needs with a smaller environmental footprint. For the next several years, 30 percent of the vehicle-replacement budget on average will be allocated to purchasing green vehicles.
- **Electric Vehicle Charging Stations**
  Planning for the equipment needs and locations of charging stations and their implementation is currently underway. This effort is being undertaken with resources outside of fleet asset-management funds.

PLANNED INVESTMENTS BY FHWA WORK TYPE

Table A.3-6 shows planned investments by work type for fleet assets.

Table A.3-6 *Planned Investments by FHWA Work Type*

Work Type	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Preservation										
Maintenance	Included within the Maintenance Levels of Service Investment Strategy									
Rehabilitation										
Replacement	$22.0	$21.5	$21.5	$21.0	$21.0	$21.0	$21.0	$21.0	$21.0	$21.0
Expansion	$0 planned									
TOTAL	$22.0	$21.5	$21.5	$21.0	$21.0	$21.0	$21.0	$21.0	$21.0	$21.0

PERFORMANCE GAP ANALYSIS

Vehicle replacements consistent with planned funding levels in the Financial Plan are forecasted to result in the fleet asset class meeting its performance target at the end of the TAMP time horizon.

PROJECTED CONDITION

As noted earlier, vehicle costs continue to increase significantly, while budgets for the Fleet asset class are expected to remain at current levels under the Financial Plan. **Figure A.3-4** shows the expected condition of CDOT's fleet asset class over time. At current funding levels, the fleet will begin to miss its 75 percent or less performance target just after the TAMP time horizon of 2031.

By 2030, Fleet Services estimates, significantly more funding will be required to address zero-emission vehicles (ZEVs) and electric vehicles. It is estimated that those vehicles will cost twice as much as vehicles with internal combustion engines.

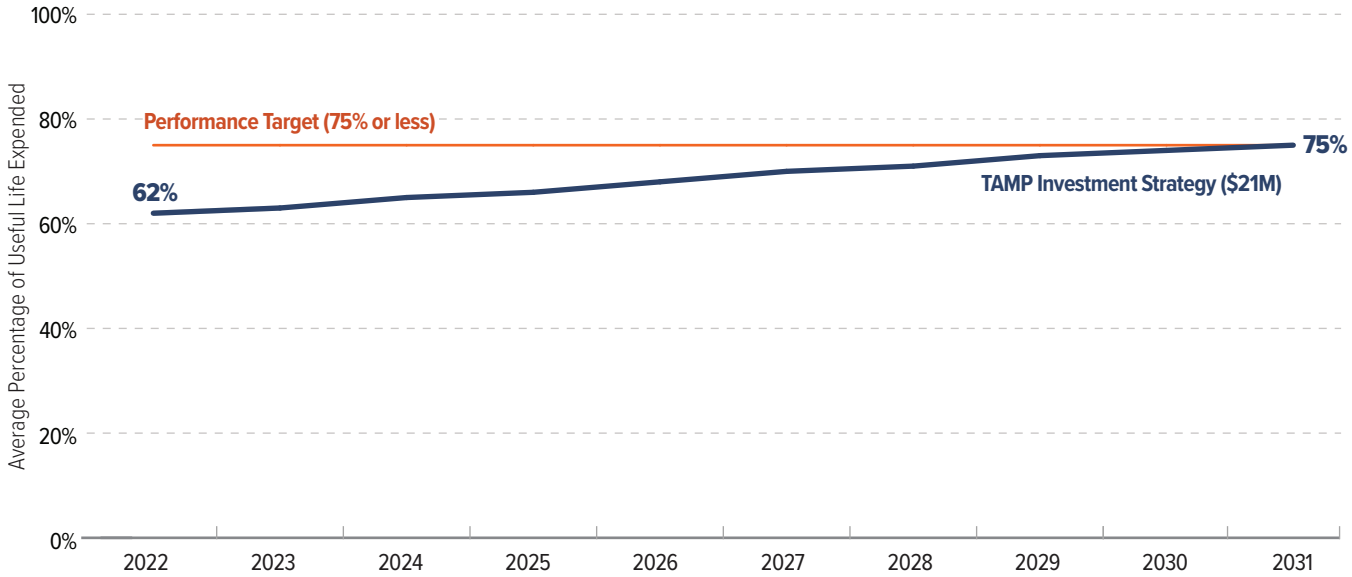
RISKS OF INSUFFICIENT FUNDING AND PERFORMANCE IMPACTS

Insufficient funding can result in delayed replacements and an older fleet, which in turn results in increased maintenance costs and lower reliability. Plows less than 14 years old have an average maintenance cost of about $13,500 per year, while plows older than 15 years have an average maintenance cost of about $21,000 per year. In addition to higher maintenance costs, an older fleet will have increased fuel costs. The fleet also will have increased out-of-service time, leading to reduced operational readiness and levels of service for highway users.

Moreover, insufficient funding is also likely to contribute to reduced parts availability, further limiting the number of vehicles in operation.

Figure A.3-4 *Projected Performance of Fleet Assets*

The anticipated annual budget of $21 million will enable CDOT to meet the performance target of ensuring that the average percent of useful life expended is less than 75%.



OPPORTUNITIES TO CLOSE THE GAP

Potential opportunities to close the performance gap besides additional funding include:

- Improved inventorying, tracking, and performance reporting to enable more robust forecasting and management of the fleet.
- Improved life-cycle analysis, including treatment recommendations, in the AIMS model.
- Standardizing vehicle specifications across CDOT Regions.

CDOT has already begun to save costs by not insisting that vehicles be painted orange. More recent vehicles are ordered and left in their white color, which also increases their resale value when disposed of by CDOT.

STRATEGIC USE OF ADDITIONAL REVENUE

Should CDOT receive additional revenue to fund the Fleet asset class, the Department's first priority is to eliminate any funding gaps related to achieving the PD 14.0 performance target. Once goals are achieved, the Department will reduce Poor backlog with a priority towards the most critical and/or vulnerable assets to improve system resilience. CDOT estimates the current "Poor" backlog for Fleet could be eliminated with about $300 million.

FUTURE IMPROVEMENTS

Intended asset-management improvements to the fleet address people, processes, and technology.

PEOPLE

CDOT's Maintenance Training Academy (MTA) is providing training to Regional Heavy Equipment Shop Supervisors on fleet maintenance management to improve the maintenance and preservation of fleet assets. The MTA also will provide training to all CDOT mechanics on the theory, safety, and maintenance of electric vehicles, which are expected to make up a larger percentage of the fleet going forward.

PROCESS

Process improvement is a key aspect of maintaining and improving the fleet asset class. Going forward, fleet asset managers will focus on continued improvements, such as:

- Extensive repairs have been completed on certain pieces of equipment to extend their useful life. A mechanism needs to be developed in the SAP software and in the AIMS model to capture the expected increase in life, as well as the repair date. Currently these pieces of equipment are manually reset in the AIMS model, so that they do not show up in near-term replacement plans. An automated reset should be developed.
- Other pieces of equipment need extensive repairs. CDOT has added a function to its AIMS model to consider such repair costs (e.g., engine repairs) and to determine if it is better to repair or replace the equipment.
- The Fleet program is currently updating policy directives and protocols related to fleet and equipment management.

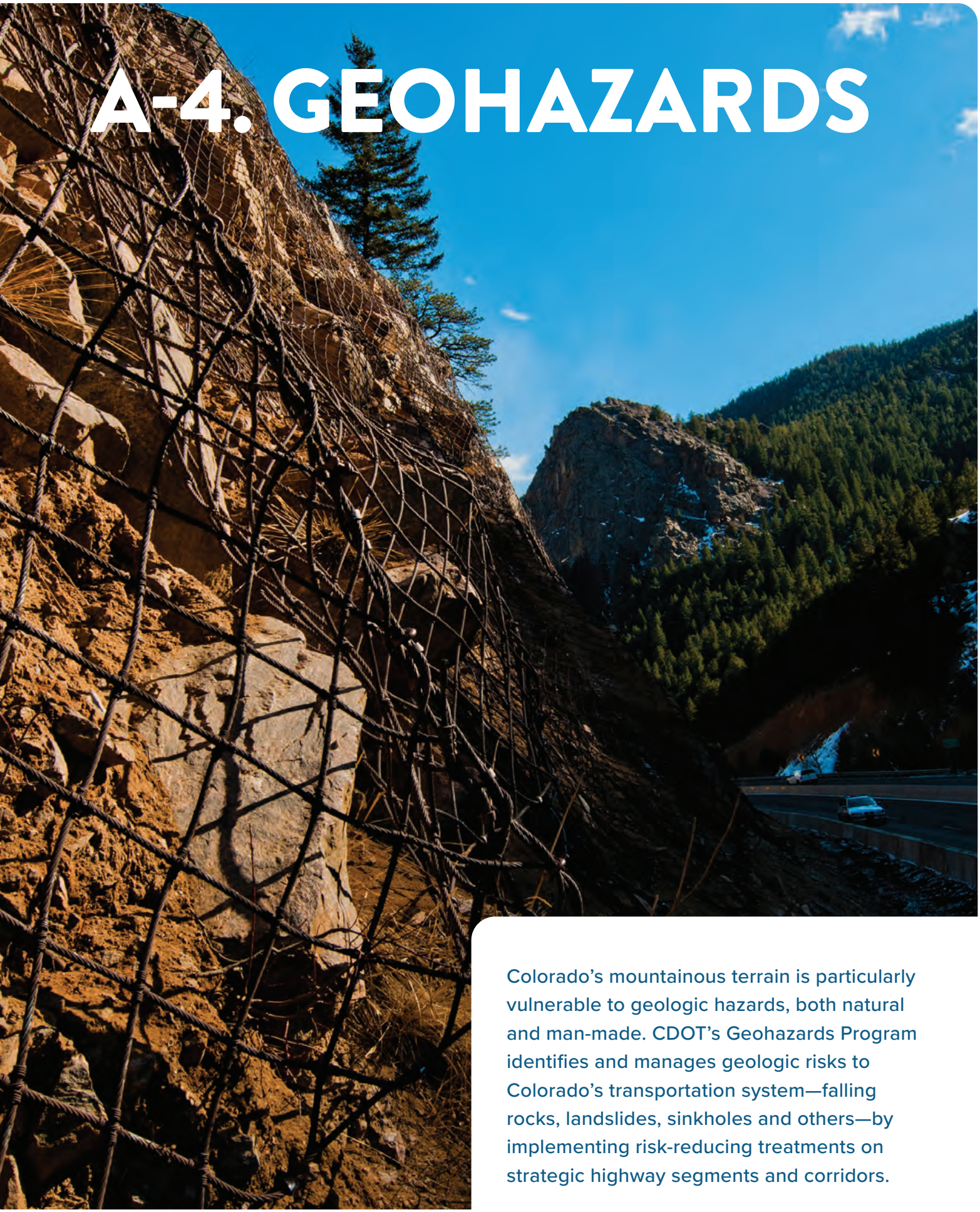
TECHNOLOGY AND ANALYSIS CAPABILITIES

Future technology and analysis improvements would establish a stronger forecasting capability and integrate more robust asset management practices.

Additionally, as part of CDOT's commitment to reduce its environmental footprint, the Fleet program continues to incorporate innovative new vehicles. This includes developing and testing a first-of-its-kind plug-in battery-powered system for bucket trucks that meets the operational needs of the fleet, only with a smaller environmental footprint. At the job site, the battery quietly and efficiently powers the truck's hydraulic lift and heating and cooling equipment—avoiding the need to idle the vehicle. Adding more green vehicles to the fleet will lower greenhouse gases and associated fuel costs. Incorporating zero-emissions vehicles into the fleet inventory and electrification of the fleet will be the focus of continuing improvements during the next 10 years.

Finally, the Fleet program is exploring the use of tools related to National Cooperative Highway Research Program Project 13-04 (Guide for Optimal Replacement Cycle of Highway Operations Equipment). These tools may give the program increased ability to produce and analyze different budgeting scenarios and replacement-cycle recommendations.

A-4. GEOHAZARDS



Colorado's mountainous terrain is particularly vulnerable to geologic hazards, both natural and man-made. CDOT's Geohazards Program identifies and manages geologic risks to Colorado's transportation system—falling rocks, landslides, sinkholes and others—by implementing risk-reducing treatments on strategic highway segments and corridors.

Geohazards are managed in alignment with the CDOT asset-management process described in the Introduction to the Asset Plan Appendix. The state's transportation system is at risk from the following geohazard events and geotechnical asset failures:

- Rockfall from natural slopes
- Rockfall from constructed rock cuts
- Rockslides
- Embankment distress
- Landslides
- Debris flows
- Sinkholes
- Subgrade distress below the pavement section

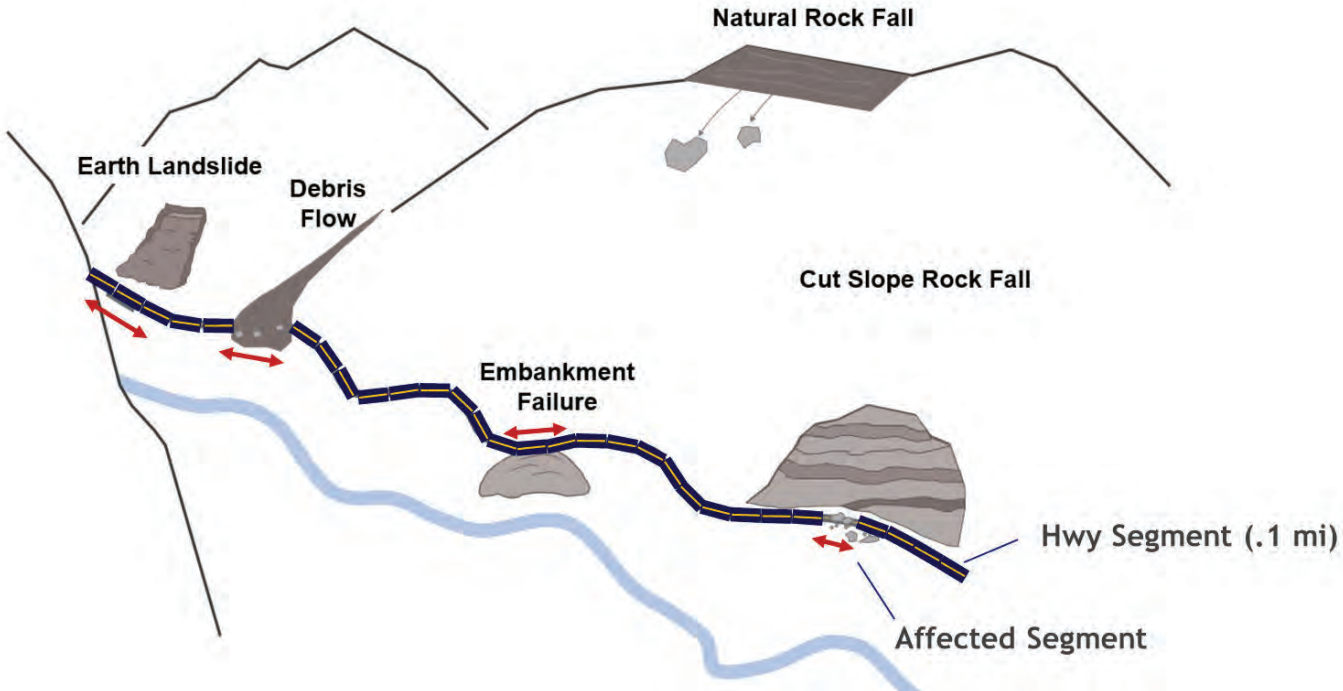
CDOT has identified and inventoried about 4,000 highway segments (0.1-mile long) threatened by geohazards. These segments are identified through a previous geologic event. Geotechnical assets such as constructed embankments are included in the inventory, following failures or observed deformation.

WHY IS GEOHAZARD MANAGEMENT FOR HIGHWAYS IMPORTANT?

Geohazards pose safety and mobility threats to users and direct costs to CDOT. The Geohazard Management System's asset management-based approach—in which CDOT uses data to rank and prioritize geohazards according to the severity of risk—is designed to lower the overall risk from geologic hazards, thus increasing safety, improving mobility for roadway users, and limiting damage to transportation assets.

Examples of the types of geohazards are shown in **Figure A.4-1**.

Figure A.4-1 *Examples of Geohazard-Affected Segments*



PERFORMANCE MANAGEMENT

Performance management for Geohazards is conducted by identifying a "Level of Risk" measure for each affected highway segment, calculated based on the likelihood of a future geological event and its associated costs.

POLICY DIRECTIVE 14.0 PERFORMANCE MEASURE

The asset management program for Geohazards (Geohazards Program) contributes to all Policy Directive 14.0 (PD 14.0) goal areas of asset management, safety, and mobility. Geohazards result in safety threats: property damage, injury, and decreases in worker safety. Proper management is essential to ensure the safety of all transportation-system users. Geohazards cause frequent highway closures and delays. The Geohazard Management Plan is a tool to measure and manage the threat to CDOT performance from geohazards. It supports the CDOT Transportation Asset Management Plan by providing additional guidance on detailed processes used within the Geohazards Program.

The performance measure in PD 14.0 for managing geohazards is the percentage of identified hazardous road segments that receive a Level of Risk (LOR) letter grade of B or better. The LOR is based on the likelihood of a geohazard event occurring, coupled with the costs created by such an event with respect to safety, maintenance, and mobility. To determine the LOR grade for a segment, an annual risk cost is first determined by the equation shown in **Figure A.4-2**.

Figure A.4-2 *Equation Calculating Annual Risk Cost for Geohazards*

The Level of Risk letter grade is then determined as presented in **Table A.4-1**.

The PD 14.0 performance target for Geohazards is for 85 percent of identified hazardous road segments to receive a Level of Risk (LOR) letter grade of B or better. This condition is considered to be a state of good repair.

Table A.4-1 *Geohazard Level-of-Risk Criteria*

Level of Risk	Annual Risk Cost
A	< $1,000
B	$1,000 - $5,000
C	$5,000 - $25,000
D	$25,000 - $50,000
F	> $50,000

Table A.4-2 shows the PD 14.0 target and 2021 performance for the Geohazards Program. The program was not achieving its target.

Table A.4-2 *Performance Metric and Target for Geohazards*

	Measure	Target	2021 Performance
GEOHAZARDS 	Percentage of hazardous road segments with a Level-of-Risk grade B or better	85%	75%

FUTURE PERFORMANCE MEASURES

The Geohazards Program is in the process of moving away from using LOR grades as a performance measure in favor of Total Annualized Risk Exposure (TARE). This measure will be incorporated into a more comprehensive risk-assessment model. The measure will be based on monetized risk instead of grade categories. The TARE measure will be calculated on a statewide and corridor basis. The new performance measurement framework is intended to improve CDOT's ability to measure risk and assess trends.

As part of broader (multi-asset) risk analysis CDOT also would like to apply the geological risk as part of a corridor-risk assessment including such prominent risks as wildfires, demographic changes, and shifts in the volume of traffic. This approach would also consider the risks to other assets, including bridges, culverts, and traffic devices.

MEASURES OF PROBABILITY AND COST

The Level of Risk for Geohazards is determined by the likelihood of a geohazard event occurring on a roadway segment and the associated costs of that event. **Table A.4-3** details how the likelihood of an event is determined, and **Table A.4-4** through **Table A.4-7** describe the estimated threat costs associated with various consequences.

Table A.4-3 *Geohazard Event Probability*

To determine the annual probability of an adverse event impacting safety, mobility or maintenance performance, an annual average event frequency is calculated for historic events. This historical analysis is updated annually.

Condition	Typical Number of Hazard Events Reported Per Segment	Annual Probability
Excellent	0	0
Good	1	0.1
Fair	2	0.2
Poor	3	0.63

Table A.4-4 *Safety Threat Levels and Associated Costs*

36 years of historical accident data was used to assign a threat level and associated cost value for each segment.

Threat Level	Historical Accident Description	Threat Cost
Low	No Reported Accidents	$0
Medium Low	1 to 20 Accidents	$3,500
Medium	3 to 4 Accidents	$10,500
Medium High	5 to 10 Accidents or Injury	$91,600
High	More than 10 Accidents or Fatalities	$6,297,000

Since 2014, improved event tracking has enabled more detailed information to be collected and from this a threat cost is assigned directly to each incident based on the costs shown in **Table A.4-5**. This actual number would replace the estimated segment cost described in **Table A.4-4**.

Table A.4-5 *Safety Threat Incident Costs*

Since 2014, when an actual incident occurs the segment safety threat-cost-per-incident is quantified using assigned costs for property damage, injury, or a fatality.

Incident Types	Cost
Property Damage	$3,500 per vehicle
Injury	$91,600 per incident
Fatality	$6,297,000 per incident

The mobility-risk cost considers the average annual daily traffic (AADT) numbers and hours for full or partial closures to quantify the total cost of mobility disruptions expected for an event, shown in **Table A.4-6**.

Table A.4-6 *Mobility Threat Levels and Costs*

The mobility threat cost is estimated based on the anticipated length of disruption, an associated cost per vehicle and the segment AADT.

Threat Level	Measured Mobility Disruption Description	Assigned Threat Cost (per Vehicle)
Negligible	No closure – only work beyond travel lanes	$0
Minor	Less than 1 hour of closure	$10.50
Major	1 to 24 hours of closure	$252
Critical	1 to 5 days of closure	$1,008
Catastrophic	More than 5 days of closure	$2,520

The maintenance cost is currently categorized in ranges, and this represents the total estimated cost to CDOT to respond to the event. This includes material for repair, and an estimate of the cost of time to complete the work.

Table A.4-7 *Maintenance Threat Levels and Costs*

Maintenance threat levels are based on estimated cost ranges. A maintenance threat cost is assigned based on an assigned value within each cost range.

Threat Level	Maintenance Cost Description	Assigned Threat Cost
Incidental	Costs are less than $25,000	$5,000
Minor	Costs range from $25,000 to $100,000	$50,000
Major	Costs range between $100,000 to $500,000	$200,000
Critical	Costs exceed $500,000	$1,000,000

Currently, the consequence side of the equation (**Figure A.4-2**) is calculated by adding the safety-risk cost, mobility-risk cost, and maintenance-risk cost.

INVENTORY AND CONDITION

CDOT identifies and inventories highway segments for which there are documented geohazard events, in 0.1-mile intervals. There are currently about 4,000 segments affected by geohazards.

INVENTORY

About 390 centerline miles, including 51 Interstate centerline miles, have a measured geohazard exposure. This represents four percent of the State Highway System.

The Geohazard inventory is stored in CDOT's Asset Inventory Management System (AIMS). The inventory of threatened highway segments includes the event count, safety impacts, road-closure impacts, and costs associated with cleanup efforts. The inventory grows as events occur and as data-collection methods improve. By late 2022, the Geohazards Program intends to have the inventory also recorded in its Cambio system. Cambio is a geohazard risk-management software used to organize event tracking and to act as the Geohazards Program's work-management and project-management system. In addition, the Geohazards Program is creating an inventory of constructed geotechnical assets (e.g., embankments) of all conditions, not just those experiencing distress. The completed inventory will also include pavement subgrades experiencing distress. Retaining walls and bridge walls that act as geotechnical assets are managed by CDOT's Walls program (Appendix A-10, Geohazards).

In addition to the highway segment and geotechnical asset inventory, the Geohazards Program also is building an inventory of geohazard-mitigation devices along CDOT highways. The current inventory includes rockfall barriers (fences), with barrier type and location data noted for each installation. Efforts are under way to expand the inventory to all mitigation types, including draped mesh, anchored mesh, rock reinforcement, attenuators, landslide-stabilization elements, and catchment ditch systems. The expanded inventory is expected to be completed in 2023.

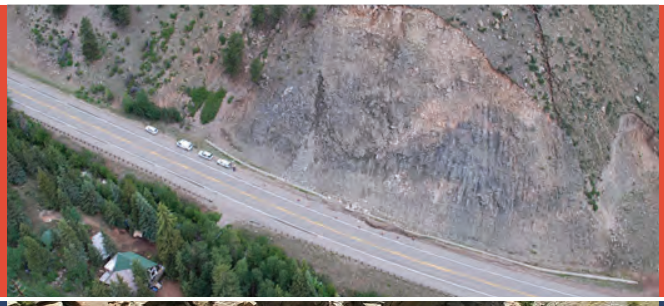
TYPES OF HAZARDS

Geological hazards that threaten the highway are varied. They include landslides, cut slopes, rockfall and rockslide events, debris flows, sinkholes, and embankment failures (**Figure A.4-3**).

Figure A.4-3 *Types of Geological Hazards*

This figure describes examples of different geological hazards that threaten highway segments in Colorado.

LANDSLIDES



Landslides can cause significant pavement cracking and can close or even destroy the roadway.

CUT SLOPES

Cut slopes are constructed geotechnical assets. Continued maintenance can reduce rockfalls from deteriorating cut slopes.

ROCKFALL

Rockfall from natural slopes can originate beyond the CDOT right of way. Like constructed slopes, natural slopes can deteriorate over time. Rockfalls from high natural slopes can significantly impact the roadway.

EMBANKMENT

Embankment (constructed soil slope) failures occur as these slopes age. They can also threaten the integrity of guardrails in some cases.

DEBRIS FLOW

The impact of debris flows on the roadway depends on the flow material, which in some cases moves with low energy and contains mostly mud. In other cases, the flow can contain large clasts that pose a threat to other assets in the path. Debris-flow likelihood increases in post-fire scenarios.

SINKHOLE

Sinkholes are relatively uncommon in Colorado but can occur where the roadway intersects underground workings, such as abandoned railroad tunnels or underground mines.

CUT SLOPE ROCKSLIDE

Rockslides from cut slopes can occur when the cut alignment intersects rock structure unfavorably. Rockfalls are smaller than rockslides and feature failing discrete blocks. Rockslides involve entire sections of slopes.

NATURAL SLOPE ROCKSLIDE

Rockslides from natural slopes are caused by discontinuities in the rock that can fail and result in a mass of rock sliding and potentially damaging and disrupting the highway.

CONDITION

"Geohazard Condition" refers to the letter grade given to each hazardous roadway segment based on current condition, historical frequencies of geohazard events, and roadway characteristics that determine the likely consequences of a geohazard event in terms of safety, mobility, and maintenance. The current condition and historic frequencies determine the likelihood of an event occurring, and the condition along with roadway characteristics determine the likely costs. These data points are used by the Geohazards Program to calculate the Annual Risk Cost and Level of Risk score, as described in Performance Management section of this Asset Plan.

CDOT typically reports performance for geohazards in terms of the percentage of hazardous road segments at or above a Level of Risk (LOR) grade B or higher.

The current (2021) percentage of segments with a grade of B or higher is 75 percent. This is below the target of 85 percent. **Table A.4-8** shows the percentage of sections currently at each LOR grade.

Table A.4-8 *Current Condition of Hazardous Road Sections*

Level of Risk Grade	Percentage of Segments
A	54%
B	21%
C	15%
D	7.5%
F	2.5%

LIFE-CYCLE PLANNING

The life-cycle management of geohazards preserves the highway system by evaluating and mitigating the risk of geohazard events through preventive maintenance and rehabilitation/ re-engineering activities.

LIFE-CYCLE PLANNING

The Geohazards Program effectively couples a risk-based asset-management strategy in the life-cycle planning of roadway assets. Roadway segments threatened by geohazards or failing geotechnical assets are first identified and included in the program's inventory, as described in Inventory and Condition section of this Asset Plan.

GEOHAZARDS LIFE-CYCLE PLANNING

Inspection and Analysis

The Geohazard Management System, a segment prioritization methodology, combines geologic, event history, and climate information with traffic and slope data to rank geohazards according to the probability and severity of the geohazard risk. Each of the identified segments is graded as to the extent (level) of the risk posed to it. The level of risk combines the probability of a geohazard event with its consequences, measured by the types of potential safety, maintenance, and mobility costs.

CDOT prioritizes sites for mitigation based on this system to mitigate the effects of geohazard events and geotechnical asset failures that have occurred, minimize their recurrence, and reduce the overall percentage of segments rated as potentially having higher annual risk costs.

The Geohazards Program intends to move toward an approach based on the geologic features likely to result in hazards on a corridor basis. The new focus places greater emphasis on management and maintenance treatments, as well as how the program can complement the asset management of other asset classes. This approach would extend the risk-assessment and management process to highway segments with a credible geohazard threat but no history of reported events.

Generation of Treatments

The Geohazard Program begins its process for generating recommended projects from its asset model when segments, location, monetized risk value, and associated segment grades are imported into the AIMS model. This information, along with deterioration models, is used to develop a recommended treatments list for hazardous road segments. Treatments for geohazards are triggered in AIMS when segments reach a risk grade of C or worse. Moving forward, segment data will be tracked/ calculated in Cambio and imported into AIMS.

There currently is only one treatment type in AIMS, which is generic "active mitigation," which is intended only for rockfalls. In future years, the Geohazards Program expects to include several hazard/asset types in AIMS and two to three treatment types for each hazard/asset to provide more meaningful modeling of treatment options. The treatment-option range will be by work types (e.g., maintenance/minor/ major/rebuild) rather than specific treatments, such as barriers or draped mesh.

PROGRAM DECISION-MAKING

TREATMENT SELECTION

On an annual basis, the AIMS modeling and analysis process is intended to generate strategies composed of one or more treatments over the analysis period. The Geohazards Program is working to include a larger variety of treatment types with more detailed and accurate costs for different geological hazards. Rockfall mitigation is the most common treatment type, particularly rockfalls from cut slopes, as rockfalls are the most common geologic hazard on state roadways.

DETERMINATION OF HIGH-RISK CORRIDORS

CDOT's geohazard project-selection process is designed to bundle projects within the same corridor to reduce risk on a corridor-wide level and efficiently allocate funding. The bundling process is conducted after the annual AIMS modeling, analysis, and budgeting process, and on an ongoing basis. Risk scores for road segments are aggregated to road corridors. These corridors are ranked based on several factors including density of geohazard risk, traffic volumes, and highway criticality. Corridors are selected based on average risk determined throughout the corridor, Region input, and activities underway within the corridor. CDOT has identified corridors with high geohazard risk, as presented in **Figure A.4-4**.

PROJECT SELECTION AND DELIVERY

After corridors are prioritized through risk levels and Region input, corridor management studies are conducted to ensure all credible geologic hazards have been identified and to determine the specific costs and benefits associated with relevant treatment options.

Corridor-management studies are the final step in the project-selection process. Factors such as geohazard event costs, event frequency, treatment applicability, constructability, mitigation effectiveness (percent mitigated), mitigation maintenance costs over time, and risk reduction are considered in the investment analysis. The studies also consider the ongoing costs associated with not treating hazard sites.

Geohazards Program staff work with consultant partners to complete the corridor management studies. The information collected and generated is incorporated into present-worth analyses of treatment options to generate benefit-cost assessments of treatments over a 30-year or greater time period. As a final step, the studies summarize the benefit-cost results for all sites within the corridor and recommend treatment packages based on available budgets, risk-reduction targets, constructability, Region capacity for delivering projects, and other considerations. The Geohazards Program then reviews the recommended treatment packages and works with Region Engineering personnel to select final sites for treatment and to deliver projects.

Figure A.4-4 *Corridors with High Geohazard Risk*

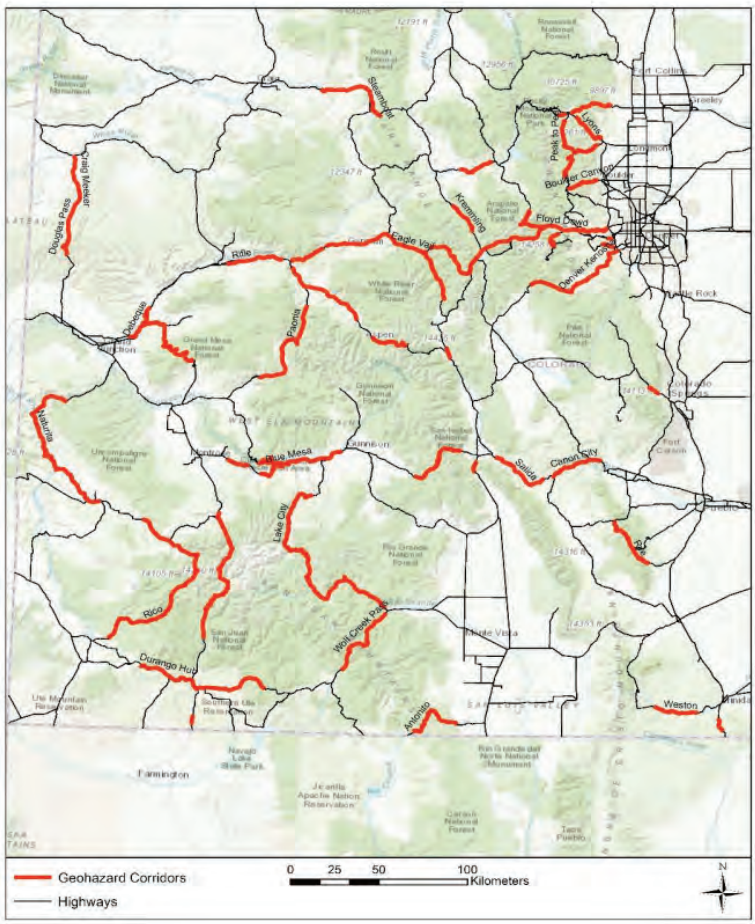


Figure A.4-5 depicts two hazardous road segments, along with potential treatments and the costs and benefits of each, which were derived from an investment study. The Geohazards Program uses such cost-benefit analyses to help choose treatments. The investment studies consider a 30-year or greater timeframe and include the life-cycle maintenance cost of the selected treatments—such as maintenance of fencing or steel-mesh slope covers—over that time.

Figure A.4-5 *Geohazards Project Selection, Cost-Benefit Analysis Example*

Benefit-cost analysis is utilized to compare different treatment options over a 50-year timeframe. The example illustrates the results from analysis of two segments on State Highway 133, and the green highlighting identifies the preferred options.

Beginning Mile Post	Ending Mile Post	Mitigated Benefit (50 year Present Worth)	Treatment Option	Risk Rating	Option Cost	Benefit / Cost Ratio
29.39	29.90	N/A	Do Nothing	N/A	$69,304,005	N/A
29.39	29.90	$ 51,978,004	A – Buttress	75%	$2,019,600	25.7
29.39	29.90	$ 34,652,002	B – Brow excavation + netting	50%	$4,199,200	15.9
29.39	29.90	$ 34,652,002	C – Brow excavation + attenuator	50%	$4,199,200	8.3
30.72	30.95	N/A	Do Nothing	N/A	$8,891,526	N/A
30.72	30.95	$ 7,113,220	A – Rock reinforcement + netting	80%	$1,132,960	6.8
30.72	30.95	$ 7,113,220	B – Soil nail wall to increase catchment	80%	$829,360	8.6
30.72	30.95	$ 7,113,220	C – Attenuator	80%	$1,821,600	3.9

Analysis and design activities undertaken by the Geohazards Program leads to the delivery of projects to help sustain the highway system in a state of good repair. Options for mitigating and repairing geohazards include regular maintenance activities conducted by maintenance crews, as well as proactive risk-reduction projects and maintenance activities performed by specialty contractors. The Geohazards Program uses CDOT asset management funding to manage needed capital investments for treatments and geotechnical assets. Definitions of the geohazard work types are summarized below.

» **Maintenance and Repair:** For many geohazard mitigation options, regular maintenance activities—such as removing debris behind barriers and fences, cleaning shoulder ditches, patching steel mesh on steep slopes, and repairing proprietary metal fence systems—are required. Maintenance crews, as part of the Maintenance Levels of Service (MLOS) program, generally perform cleaning of shoulder ditches and some embankment repairs. These crews also respond to emergency geohazard events, such as rockfalls and landslides, by clearing roadways. More specialized work, such as repairing mitigation infrastructure (e.g., rockfall netting), is generally performed by specialty contractors under the management of the Geohazards Program.

» **Rehabilitation/Reconstruction/Replacement:** Capital investments in treatments and geotechnical assets (other than walls) are managed by the Geohazards Program using CDOT asset management funding. As noted earlier, work

management for these projects is supported by the Cambio system. After the preferred treatments for a corridor are selected, the Geohazards Program is responsible for managing and overseeing the design of the projects (the actual design work is generally performed by consultants). The program then works with CDOT's Regions, which provide the project managers for, and manage the construction of, the new treatments. Construction is generally performed by contractors. As part of the new TARE performance-management framework, there will be a greater emphasis on the performance and life-cycle management of geotechnical assets, rather than the current focus on replacement.

» **Initial Construction:** The Geohazards Program has not, heretofore, had the ability to translate what is learned from the identification of failing geotechnical assets such as embankments into the improved design of new highway segments with the same features. Many embankments were created before current CDOT design standards. In moving beyond the event-driven inventory and approach of the past, the Geohazards Program hopes to use the new data it collects on asset deterioration, and its analysis of root causes of failure, to inform a more comprehensive CDOT highway-design program. This more comprehensive design program is envisioned to incorporate geologic information—including the appropriate geohazard-avoidance mechanisms and best geotechnical asset design—in the construction or reconstruction of new roadway segments.

About 40 percent of the Geohazards Program's budget is devoted to operations/design and emergency response, with the remainder invested in mitigation treatments.

The types of geohazard-management treatments undertaken by CDOT are classified according to Federal Highway Administration (FHWA) work types in **Table A.4-9**.

Table A.4-9 *Geohazards Treatments by Work Type*

FHWA Treatment Work Type	CDOT Activities
Preservation/Routine Maintenance	Activities that prolong the life of the asset and do not require design or physically working on the asset itself. Examples are cleaning rockfall debris from catchment ditches to retain the designed catchment capacity, or cleaning culverts to prevent water from infiltrating into and destabilizing embankment slopes. These activities are typically, but not always, performed by the MLOS program.
Maintenance	Activities or repairs that prolong the life of the asset without improving its performance rating. Examples include rock scaling to remove loose rock from a deteriorating slope, installation or maintenance of drainage elements in landslides or embankments, and repair of previously installed mitigation elements such as rockfall barriers or draped wire mesh.
Rehabilitation	Major treatments intended to prolong the life and increase the performance of poorly performing assets. Examples include: rockfall barriers, draped wire mesh, attenuators, and/or rock reinforcement installed on rockfall-prone slopes; landslide stabilization using installed elements such as tie-backs, deep foundations, or lightweight fill; embankment stabilization using installed structural elements such as soil nails, deep patches, or micropiles; and debris-flow mitigation using constructed elements such as barriers, detention basins, or oversized culverts.
Reconstruction/ Replacement	Complete replacement of a geohazard management asset, such as a rock slope or embankment. Example would be a sliver cut/layback excavation of an entire existing rock face using slope-stability blasting techniques to improve stability within the face and increase ditch catchment. Additional stabilizing elements such as shotcrete, rock anchors, or draped mesh may be installed along with the excavation as a part of this work.
Initial Construction	Construction of a rock cut slope, or earth embankment where none existed, as part of a capacity increase or realignment. For example, the proposed US 287 realignment would create new rock cuts, and these assets would be managed by the Geohazards Program. Exposure of the highway to new hazards on natural slopes as a result of expansion/capacity increases also qualifies as initial construction.

RISK MANAGEMENT

The Geohazards Program tracks and quantifies risk to the transportation system posed by geohazards. Risk is considered with regard to safety, mobility, and impacts to other asset classes. The program has been moving toward monetized risk as a metric to help determine the value of investments in preventive structures and treatments. Moving to a monetized risk approach will provide greater flexibility to identify locations at risk before a hazardous event occurs and improve CDOT's ability to measure risk and assess trends. Section 6 of the TAMP provides more information about CDOT's risk-management methodology and processes, including an explanation of elements comprising risk scores.

The Geohazards Program maintains a register of risks to its overall program and projects. The top risks identified are shown in **Table A.4-10**.

Table A.4-10 *Top Geohazards Risks*

Risk Level	Threat	Risk Score[1]	Risk-Management Strategy
Multiple	Landslide causing loss of road and long-term mobility impacts/delays	56 (T)4 x (C)3.5 x (V)4	Treat or tolerate, depending on the area
Multiple	Rockfall incident with fatality	50.4 (T)3 x (C)4.2 x (V)4	Treat or tolerate, depending on the area
Multiple	Sinkholes resulting in road closure of at least several hours	48 (T)4 x (C)3 x (V)4	Tolerate
Multiple	Rockfall with loss of function/mobility for several days	46.8 (T)4 x (C)3.9 x (V)3	Treat or tolerate, depending on the area
Multiple	Severe weather event causing debris flows that damage pavement, culverts, or structures	46.8 (T)3 x (C)3.9 x (V)4	Tolerate
Multiple	Post-fire debris flows and resulting closures	44.4 (T)4 x (C)3.7 x (V)3	Treat or tolerate, depending on the area

1 Risk Score = Threat Likelihood (T) * Total Consequence and Consideration Score (C) * Vulnerability (V)

FINANCIAL PLAN

CDOT sets planning budgets for Geohazards and other asset programs four years in advance. Beginning in FY24, the Department estimates static annual funding levels for geohazards through FY31. These estimates, combined with CDOT's life-cycle management approaches discussed in the previous section, inform the investment strategies CDOT plans to leverage to achieve system-wide asset performance goals while minimizing life-cycle costs.

FUNDING SOURCES

Funds for the Geohazards Program are derived from CDOT's Transportation Asset Management program. Funding for geohazard preservation comes from the MLOS program and is included in the MLOS financial plan.

PLANNED FUNDING

The 10-Year Financial Plan for Geohazards is shown in **Table A.4-11**. The figures presented include a $2 million per year contingency for unplanned work, and $2 million per year set aside for anticipated maintenance of slopes and mitigation systems.

For the first several years of this 10-year period, the budgets shown below have been adopted by the Transportation Commission as "planning budgets." Beyond FY 2027, the budgets in **Table A.4-11** represent an assumption that Geohazards funding will remain at static levels for the time horizon of the TAMP.

Table A.4-11 *Financial Plan for Geohazards (in Millions)*

FY22	FY23	FY24	FY25	FY26	FY27	FY28	FY29	FY30	FY31
$10.1	$10.0	$9.7	$9.7	$9.7	$9.7	$9.7	$9.7	$9.7	$9.7

INVESTMENT STRATEGIES

Future investment strategies for the Geohazards Program will look much like current practice, assuming the steady-state funding presented in the Financial Plan. Investment strategies are, at a high level, spelled out in the Geohazards Management Plan. Corridor-management studies then define the specific strategy as described in the Life-Cycle Planning section of this Asset Plan.

BACKGROUND: DETERMINING INVESTMENT STRATEGIES

The current draft of an update to the Geohazards Management Plan focuses on three investment strategies:

Strategy 1—Conducting preventive maintenance. While maintenance for many geohazards and accompanying mitigation devices is performed reactively, some mitigation can be performed on regular intervals, such as scaling to reduce the amount of rockfall at specific locations.

Strategy 2—Assessing preventive maintenance cost-effectiveness to identify alternative mitigation methods. Mitigation devices are evaluated on the need to repair the device or update the mitigation method. For example, if a concrete barrier used to enhance a rockfall catchment ditch requires replacement more than once per year, an updated mitigation strategy might offer an alternative with similar or higher level of protection, such as installation of rockfall netting.

Strategy 3—Enhancing the Geohazards program to reflect an asset management approach. Examples include:

- Provide a site-selection guideline that mitigates rockfall hazards identified in the Colorado Rockfall Hazard Rating System.
- Manage existing geohazard assets constructed by previous projects or installed by CDOT Maintenance staff.

PLANNED INVESTMENTS

Potential investments by the Geohazards Program are categorized by corridor and hazard type in corridor-management studies as described in the Life-Cycle Planning section of this Asset Plan. Nearly all the treatments will fall into the Rehabilitation work type described in **Table A.4-9**. Maintenance work is performed as part of CDOT's MLOS program. Reconstruction or replacement projects will be relatively rare.

Examples of projects planned and programmed for the next few years are shown below.

Figure A.4-6 *Examples of Planned and Programmed Projects*

PERFORMANCE GAP ANALYSIS

CDOT's Asset Investment Management System (AIMS) model predicts the long-term performance of the Geohazards Program, given various funding scenarios. This allows CDOT to evaluate how different spending levels will impact performance. Planned spending is expected to result in a relatively stable condition rating, but the program is not forecasted to meet its performance target.

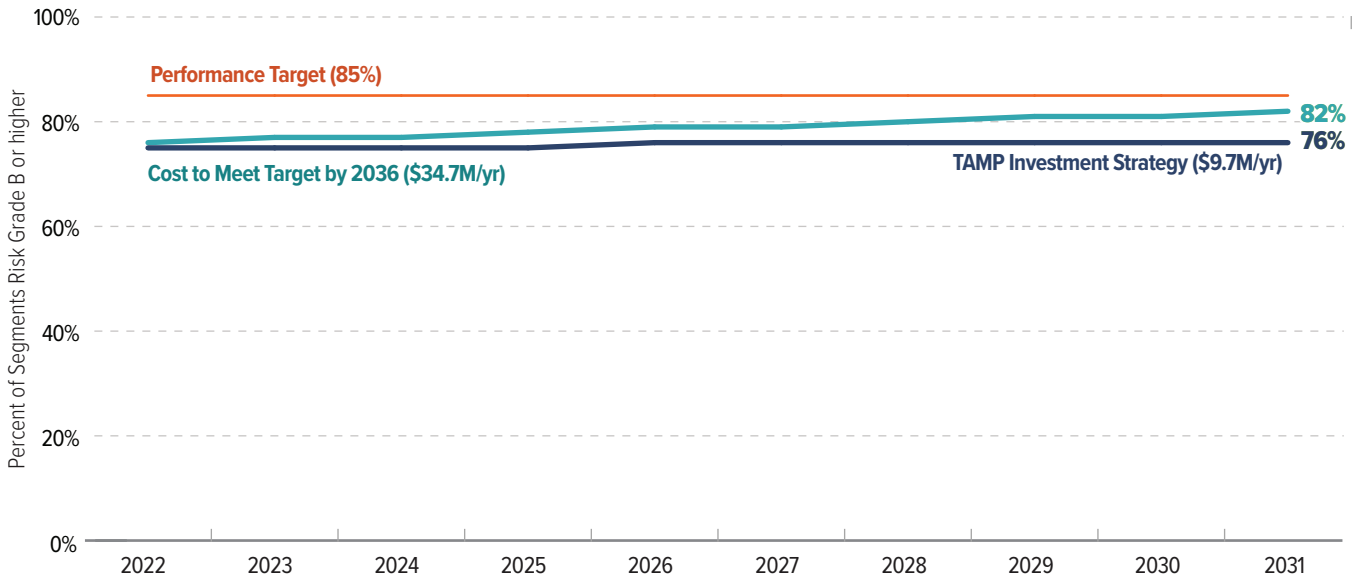
NEEDS AND PROJECTED CONDITION

CDOT's AIMS model predicts the long-term performance of geohazards assets given the Financial Plan. The AIMS model predicts future condition and generates a list of alternative strategies for each segment. Various budget scenarios are then optimized to determine performance impacts and a recommended construction program. These scenarios assume that $2 million per year of the Geohazards budget will be set aside as a contingency for unplanned work, and $2 million per year will be set aside for anticipated maintenance of slopes and mitigation systems.

Geohazards are not forecasted to meet CDOT's target under Financial Plan funding levels, but performance is expected to improve slightly over time. **Figure A.4-7** shows the expected percentage of hazardous road sections with a grade of B or better over time given the Financial Plan. As the graph shows, more than $25 million in additional funding annually would be needed to achieve the target by 2036.

Figure A.4-7 *Projection of Risk Grade for Geohazards*

The anticipated annual budget of $9.7 million will not meet the performance target of ensuring that the average percent of segments with a risk grade B or higher is greater than 85 percent. The annual cost of meeting the target by 2036, is about $34.7 million, or an additional $25 million per year.



RISKS OF INSUFFICIENT FUNDING

Insufficient funding for geohazards assets may result in:

- Acceptance of a higher level of risk.
- Transfer of geohazard risk to other asset classes and roadway users in the form of added repair and maintenance costs and service interruptions.
- Decreased inspections and maintenance work, increases in construction time, and fewer proactive geohazard-mitigation projects.
- Moving away from life-cycle planning focused on preventive maintenance toward increased reliance on emergency response.

The impact on other assets from geohazard events is illustrated in **Figure A.4-8**.

Figure A.4-8 *Impact of Geohazards on Other Assets*

As an example of geohazard impacts, landslides can result in service interruptions and create increased repair and maintenance costs for a range of CDOT asset classes.

OPPORTUNITIES TO CLOSE THE GAP

The Geohazards Program intends to seek additional Risk and Resilience program funding to support faster cleanups following events, fewer delays for users, and less damage to other assets. In addition, the Geohazards Program may provide design support to projects and other asset classes. This will help ensure that geohazard risk-reduction elements are built into those projects and into the ongoing management of other asset classes.

STRATEGIC USE OF ADDITIONAL REVENUE

Should CDOT receive additional revenue to fund the Geohazards asset class, the Department's priority is to eliminate any funding gaps related to achieving the PD 14.0 performance target. Once goals are achieved, the Department will apply the processes described here to prioritize the most critical and/or vulnerable assets to improve system resilience. CDOT estimates the current backlog for Geohazards could be eliminated with about $391 million.

FUTURE IMPROVEMENTS

Future improvements to geohazards management will address people, processes, and technology. This includes improving collaboration among personnel, moving from an event-based to a risk-based geohazards inventory, and improved data collection and analysis.

STAFF

The Geohazards Program intends to improve asset-management capabilities by fostering closer collaboration with Region Maintenance and Engineering personnel to facilitate more accurate and comprehensive event-data collection.

PROCESS

Because geohazard risk is not limited to sites where an event has taken place, the Geohazards Program plans to move from an event-based inventory to one that more holistically determines the risk to road segments. Key improvements to evaluating risk will include incorporating more data points, such as infrastructure type, infrastructure forecasting using rating data, weather information, and change-detection data. These data will help improve risk modeling.

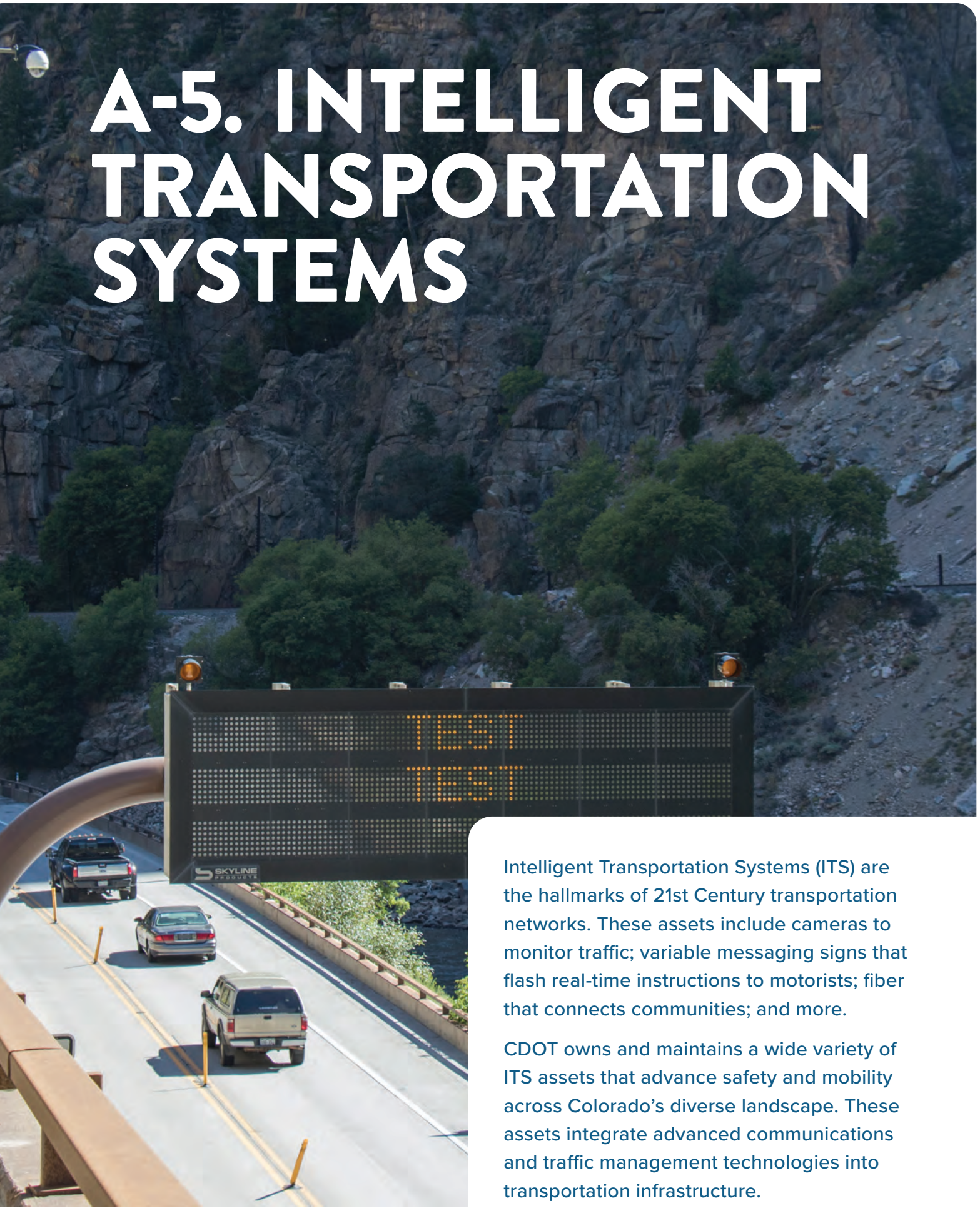
Additionally, 0.1-mile road segments are inventoried by CDOT if they have had a geohazard event. However, conditions that cause an event on one segment may be present along nearby road segments as well. Therefore, the Geohazards Program hopes to inventory all high-risk segments in the area of an event. The improved inventory would more accurately reflect the hazard area and provide greater accuracy and insight into the benefit of mitigation.

TECHNOLOGY AND ANALYSIS

Future technology and analysis improvements will establish improved data collection and forecasting, and integrate more robust asset management practices. The Geohazards Program will leverage new sources of data from technology such as remote sensing, enabling a shift from the current inventory that only tracks segments where a geohazard event occurred.

Additionally, the Geohazards Program intends to develop improved deterioration models for mitigation devices, geotechnical assets, and geohazards, and to measure the benefits of mitigation better. These improvements will enable CDOT to better forecast performance and choose mitigation projects.

A-5. INTELLIGENT TRANSPORTATION SYSTEMS

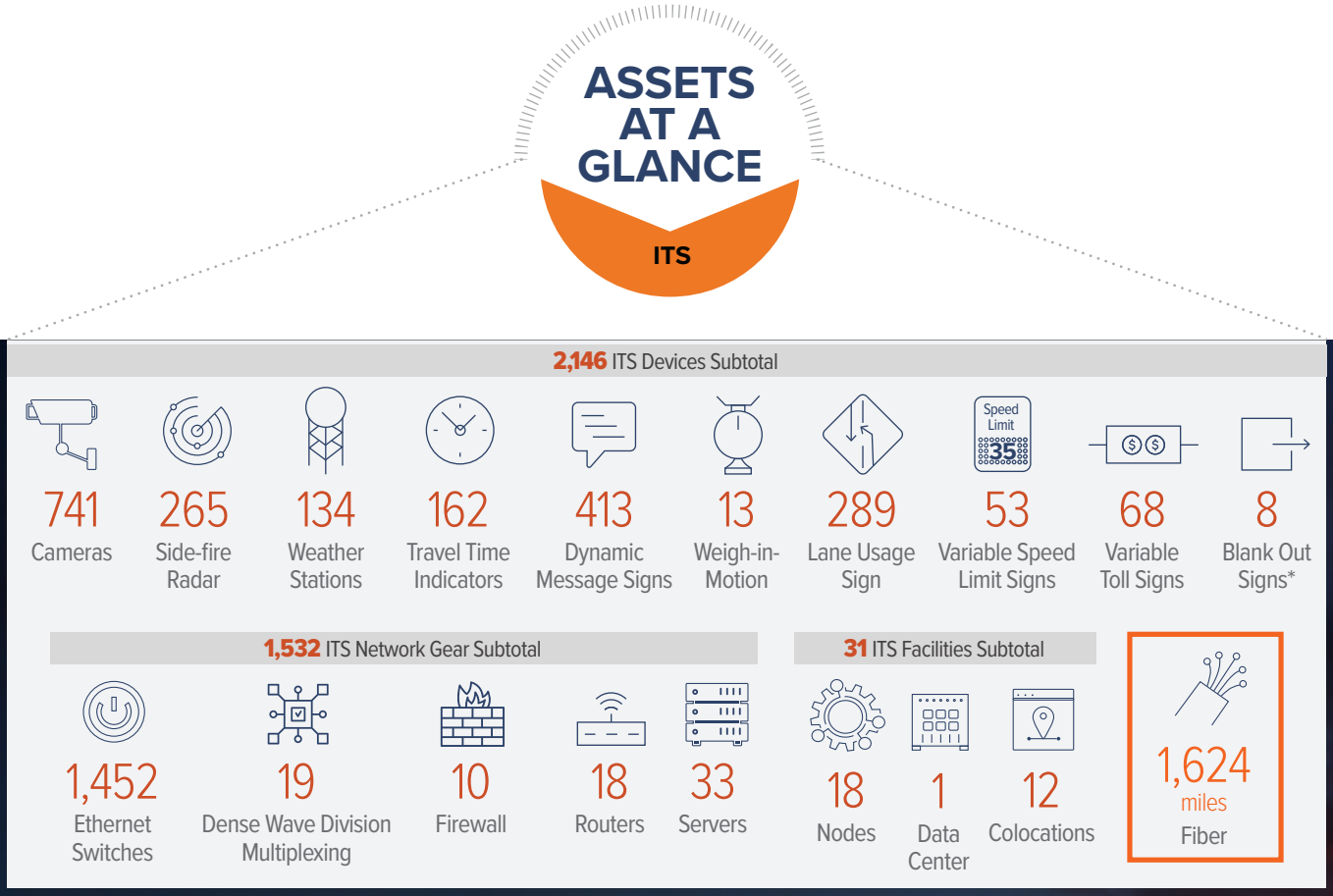


Intelligent Transportation Systems (ITS) are the hallmarks of 21st Century transportation networks. These assets include cameras to monitor traffic; variable messaging signs that flash real-time instructions to motorists; fiber that connects communities; and more.

CDOT owns and maintains a wide variety of ITS assets that advance safety and mobility across Colorado's diverse landscape. These assets integrate advanced communications and traffic management technologies into transportation infrastructure.

ITS are managed in alignment with the CDOT asset-management process described in the Introduction to the Asset Plan Appendix.

Figure A.5-1 *ITS Assets at a Glance*



National Highway System (NHS)

Selected Asset Descriptions:

Blank Out Sign: *Signs only active during certain times and conditions that display information to motorists such as road closures, detours, and prohibited turns.*

Ethernet Switch: *Network hardware that connect cabled devices so they can communicate with each other and to the internet.*

Dense Wave Multiplexing: *Optical technology that is used to increase the bandwidth of fiber networks.*

Firewall: *A security device used to prevent or limit illegal access to private networks.*

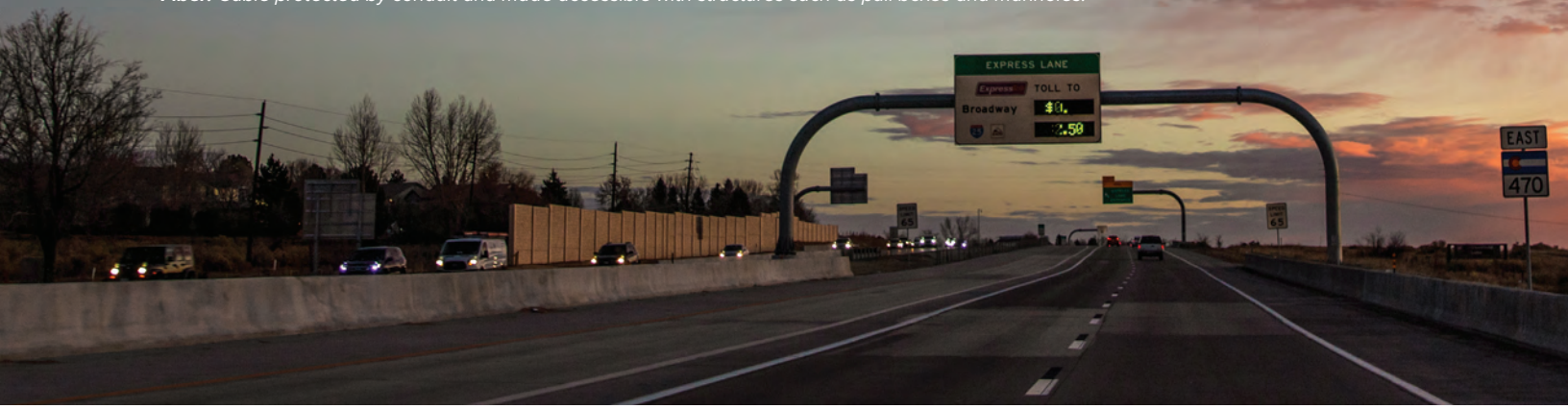
Router: *A device that connects between networks, it routes packets from one location to another.*

Server: *A device that receives, stores and shares data.*

Node: *A building that houses connection points among network devices such as routers and switches that can receive and send data.*

Colocation: *A building that houses third-party network equipment as well as CDOT's own network gear.*

Fiber: *Cable protected by conduit and made accessible with structures such as pull boxes and manholes.*



PERFORMANCE MANAGEMENT

CDOT monitors and manages the performance of ITS assets as part of its performance management framework, using quantitative measures and targets that inform funding decisions and track how well these assets are supporting the agency's strategic goals and services provided to the public.

POLICY DIRECTIVE 14.0 PERFORMANCE MEASURE

CDOT's asset management program for ITS helps meet goals for safety, asset management, and mobility established under Policy Directive 14.0 (PD 14.0). ITS assets are critical for collecting and communicating safety information to vehicles. This includes weather stations collecting data that can then be shared as a warning of dangerous conditions. They enhance mobility by providing critical data to inform vehicle operators with up-to-date traffic information, optimizing the speed of traffic through variable message signs or managing the amount of traffic entering freeways through ramp-metering devices.

The specific performance measure in PD 14.0 for maintaining a state of good repair of ITS assets is the average percent "useful life" expended of all ITS equipment. Useful life, which is specific to each device type, is defined as the length of time that a device is expected to provide CDOT with adequate data and information. The "percent useful life expended" of an ITS device is calculated by dividing the device age by the device life cycle. A value of 100 percent indicates that a piece of equipment has reached its useful life. Values greater than 100 percent indicate the equipment has exceeded its useful life.

Table A.5-1 shows the PD 14.0 objective target and 2021 performance for ITS assets.

For federal TAMP purposes CDOT defines state of good repair based on the measures presented in PD 14.0. The current (2021) average percent useful life expended of ITS equipment is 70 percent, which is within the target of 90 percent.

OTHER PERFORMANCE MEASURES

CDOT's ITS Branch is gradually incorporating device functionality into its performance measures that help inform asset management investments. The branch defines functionality as the device's primary purpose, and has created five functionality categories: regulatory, safety, mobility, data support, and system support.

As CDOT transitions into managing ITS assets by service packages[1], adopting metrics that measure the availability of systems (e.g., mean time to recovery, or MTTR) will assume greater importance in assessing asset performance.

Table A.5-1 *Performance Metric and Target for ITS*

ITS

Measure	Target	2021 Performance
Average percentage of useful life expended	≤90%	70%

1 A hierarchy of multiple assets and components (parts of assets) that deliver technology solutions.

INVENTORY AND CONDITION

CDOT tracks ITS assets and their useful life within the ITS Branch's geographic information system (GIS). The ITS Branch maintains rigorous standards to ensure the accuracy and completeness of the inventory and conducts regular audits and cross-checks with other CDOT systems to prevent double counting. CDOT assesses condition of its ITS assets each year by evaluating the percent of useful life expended for each asset.

CDOT owns and maintains a total of:

- 2,146 ITS devices
- 1,532 pieces of ITS network gear
- 1,624 miles of fiber cable
- 31 ITS facilities

The ITS equipment inventory is presented in **Table A.5-2**. It excludes:

- Ramp metering stations and automatic traffic recorders.
- ITS equipment in the Eisenhower-Johnson Memorial Tunnel. Equipment is being replaced through 2022, and the new equipment will be included in the inventory thereafter.
- ITS equipment on traffic signals.
- Cabinets and switches—The ITS Branch intends to bring these assets into the ITS management system in the near future (see page A-91, Future Improvements).

Figure A.5-2 *Examples of ITS Assets Inventory*

Table A.5-2 *Inventory of ITS Assets (2021)*

ITS Asset Type	Count
Cameras	741
Side-Fire Radar	265
Weather Stations	134
Travel Time Indicators	162
Dynamic Message Signs	413
Weigh-in-Motion	13
Lane Usage Sign	289
Variable Speed Limit Signs	53
Variable Toll Signs	68
Blank-Out Signs	8
ITS Devices Subtotal	2,146
Ethernet Switches	1,452
Dense Wave Division Multiplexing	19
Firewall	10
Routers	18
Servers	33
ITS Network Gear Subtotal	1,532
Nodes	18
Data Center	1
Colocations	12
ITS Facilities Subtotal	**31**
Fiber	**1,624 miles**

The ITS asset inventory is maintained and managed in the ITS Branch's Geographic Information System (ArcGIS Pro). Work orders for maintenance and repair of ITS assets are issued and managed through CDOT's SAP Enterprise Resource Planning (ERP) system.[2] The ITS inventory is duplicated in SAP.

Inventory-management processes include multi-step workflows for documenting ITS assets through add/change/remove (ACR) form and for taking assets offline and restoring them to the inventory, as well as regular audits. These processes are critical to ensure that teams working in the field have accurate device information.

SERVICE PACKAGE ASSET HIERARCHIES

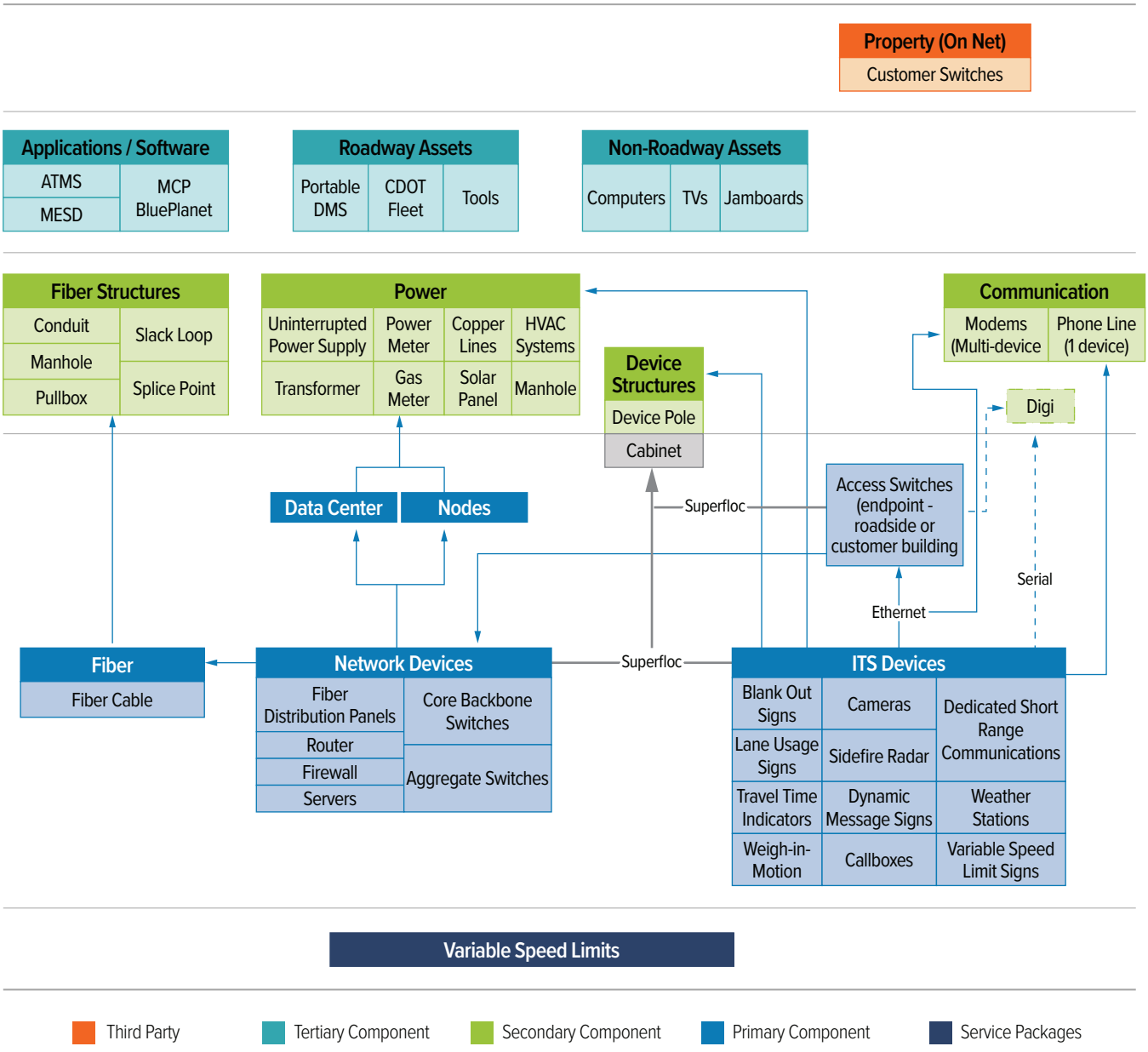
While the inventory presented in **Table A.5-2** counts each asset type as unique, ITS assets are managed as "service packages" to address a specific objective of the highway system. A service package is a hierarchy of multiple assets and components (parts of assets) that deliver technology solutions.

Service packages can improve efficiency. For example, an ITS sign can be used within different service packages depending on the intended function (e.g., speed control or hazard warning), and knowing the function(s) at the start of the asset's life-cycle planning phase can reduce costs. An example of a service package would be deploying a variable speed-limit system along a corridor to mitigate weather-related crash patterns. The hierarchy of such a service package is illustrated in **Figure A.5-3** below and features a range of assets including cameras, Dynamic Message Signs, Weather Stations, and others.

2 SAP, an acronym for "Systems, Applications and Products in Data Processing," is an Enterprise Resource Planning system that CDOT installed in 2006.

Figure A.5-3 *Variable Speed-Limits Service Package: Asset Hierarchy*

A Variable Speed Limit service package requires multiple assets. These include primary component assets including fiber, ITS and network devices. To support these devices, there are secondary and tertiary components (parts of the assets) critical to delivering the service package outcomes.



Selected Asset Descriptions:
ATMS: Active Transportation Management System (application for operations centers to operate ITS device on the road)
DMS: Dynamic Message Sign
MCP BluePlanet: An application for network monitoring
MESD: Manage Engine Service Desk (ticketing application)

Federal regulations[3] require the development of an ITS architecture that guides the development of ITS projects and programs, based on a Systems Engineering Analysis (SEA). The purpose of the architecture and the SEA is to ensure thoughtful spending on technology deployment at all transport agencies. Service packages can deliver the architecture outcomes and be the product of an SEA.

Because of the interrelationships of assets and components in a single service package "system," the failure of a key component can have a domino effect, causing the entire system or service package to fail. Additionally, replacing an application used by CDOT's traffic operations centers to operate and control technology service packages on highway corridors can impact multiple service packages. An example would be replacing CDOT's Corridor-Trip Monitoring System, or CTMS, with a new Advanced Traffic Management System, or ATMS, application. While ITS investment decisions are structured consistent with the architecture and SEA, the ITS Branch must monitor the useful life of assets within each system at the component level and plan for component replacements accordingly.

CONDITION

CDOT uses the expended life of an ITS asset as a proxy for measuring the condition of the equipment. Each device type has a specific period of useful life, which is the length of time the device is expected to provide CDOT with adequate data to serve the public.

The Intelligent Transportation Systems Branch (ITS Branch) determines the useful life of an ITS asset. The determination is based on the manufacturer's specification and considers recommendations from the ITS Branch's maintenance personnel and the Federal Highway Administration's (FHWA's) list of ITS device life cycles. FHWA conducts state surveys and compiles the results to develop its device life-cycle list.

Additional considerations when determining useful life include:

- Changing technologies such as software advances that may affect maintenance costs or the ability to assimilate data from the device.
- Obsolescence.
- General maintenance costs.
- Geographic locations of the device (e.g., assets at 8,000 feet, where snow is likely, or at 4,500 feet on plains where high winds and snow occur, are more likely to require attention).

In some cases, ITS assets have been devolved from local authorities to CDOT control. For such assets, the ITS branch has begun assessing an asset's age from the first time it was inventoried, either by CDOT or the original asset manager.

Each device's percentage of expended life is calculated annually by dividing its age by its expected useful life. Based on this information, an average percentage of life expended is calculated for the entire ITS asset class. **Table A.5-3** presents current condition data for ITS assets.

3 23 Code of Federal Regulations Part 940

Table A.5-3 *Condition of ITS Assets (2021)*

Asset Type	Count	Useful Life	Average Life Expended
Cameras	741	5	108%
Side-fire Radar	265	7	75%
Weather Stations	134	12	60%
Travel Time Indicators	162	7	92%
Dynamic Message Signs	413	20	36%
Weigh-in-Motion	13	7	120%
Lane Usage Signs	289	12	44%
Variable Speed Limit Signs	53	10	36%
Variable Toll Signs	68	10	56%
Blank Out Signs	8	7	74%
ITS Devices	2,146		70%
Ethernet Switches	1452	7	63%
Dense Wave Division Multiplexing	19	7	80%
Firewall	10	7	86%
Routers	18	7	54%
Servers	33	7	84%
ITS Network Gear	1,532		69%
Nodes	18	25	34%
Data Center	1	25	32%
Colocations	12	25	38%
ITS Facilities	31		34%
All Devices, Network Gear and Facilities			70%
Fiber	1,624 miles	20	Not currently tracked[4]

ASSET VALUE

CDOT in 2022 assessed the value of ITS assets. The current replacement value is $133 million and is determined by acquisition value.

To calculate current asset value, the replacement value is discounted by the ratio between the age of the asset and the expended useful life of the asset. The current value of ITS assets is $126 million.

A separate valuation was calculated for fiber-optic assets, which have a replacement value of $325 million.

4 In most cases, CDOT relies on private partners for installation and maintenance. CDOT only has use of a portion of the fiber. Additionally, it is difficult to measure fiber condition, as its location underground hinders visual inspection.

LIFE-CYCLE PLANNING

The life-cycle management of most ITS assets is the responsibility of the ITS Branch of the Division of Maintenance and Operations. CDOT's approach to the life-cycle management of ITS assets is primarily age-based. This approach helps minimize asset failures and reduces uncertainty in funding needs.

LIFE-CYCLE PLANNING

The expected life of ITS assets is primarily estimated based on age (age-based)—as assets age, performance and reliability can decrease, putting the assets at risk of failure. Environmental factors, such as harsh weather events and geographic location, can also affect asset performance. Moreover, assets may become obsolete as various ITS technologies advance. As a result of these factors, different types of ITS assets have different lifespans. An age-based approach to life-cycle planning can minimize asset failure and reduce uncertainty in funding needs.

ITS LIFE-CYCLE MANAGEMENT APPROACH

The performance measure for CDOT's age-based life-cycle strategy is the percentage of device life expended, as described in the Asset Inventory and Condition section of this Asset Plan. CDOT's Asset Investment Management System (AIMS) model uses this metric, along with cost data from CDOT's SAP financial software, to inform recommended treatments. These recommendations are currently limited to device replacements. The ITS Branch considers the recommended replacements in its life-cycle planning strategies and decision-making.

Through life-cycle planning, CDOT is able to project how ITS assets are expected to perform over the long term. The AIMS model forecasts the long-term performance of the ITS assets given the expected expended life of each asset type and the level of funding required to meet the PD 14.0 performance target. ITS devices and Ethernet switches are currently included in the AIMS modeling.

PROGRAM DECISION-MAKING

TREATMENT SELECTION

The ITS Branch uses the AIMS model to help develop annual treatment lists for a rolling four-year period. Treatments can become standalone projects or be bundled into projects encompassing multiple treatments.

Although the ITS Program is a statewide program, each year requests are sought from CDOT Regions regarding their needs for maintaining or acquiring new ITS assets.

Maintenance/Rehabilitation/Reconstruction

The ITS Branch performs preventive and reactive maintenance and repair of ITS assets. Maintenance activities include preventive maintenance, such as road weather sensor (RWS) calibration; day-to-day maintenance, such as camera cleaning; inspections and fiber locations; and emergency repairs (e.g., repairs to fiber outages).

In recent years, maintenance activities have received the majority of ITS asset management funding. Such activities include camera maintenance, testing and maintaining security systems, and more. Much of the ITS maintenance program is reactive (e.g., troubleshooting, emergency response), rather than proactive treatments that improve asset condition or extend asset life.

Reactive or corrective maintenance is particularly relevant to the ITS fiber-cable network. There is not an industry best practice for the proactive replacement of fiber cables or fiber-cable infrastructure. Often maintenance activities are driven by damages. Fiber-cable damage can be minimized by having a robust fiber location program that accurately marks fiber cable's location before construction or maintenance activities begin.

Within the ITS Field Operations team, there is a full-time staff focused on fiber. This team manages a fiber-location program, responds to fiber-locate issues and fiber cuts, and investigates outage causes. The team also addresses emergency repairs, new cable inspections, and fiber allocation requests.

CDOT tracks each device within its ITS Management database (contained in SAP financial software). Work orders are used in the performance of all maintenance activities to monitor and report device condition and maintenance costs.

ITS maintenance costs are increasing as new infrastructure is added (e.g., managed lanes). Because ITS works within constrained budgets, this means the amount of funding available for device replacement decreases.

Replacement

ITS receives funding from sources other than asset management to replace ITS infrastructure. Several years, in fact, there has been no funding available for proactive replacement through asset management.

Initial Construction

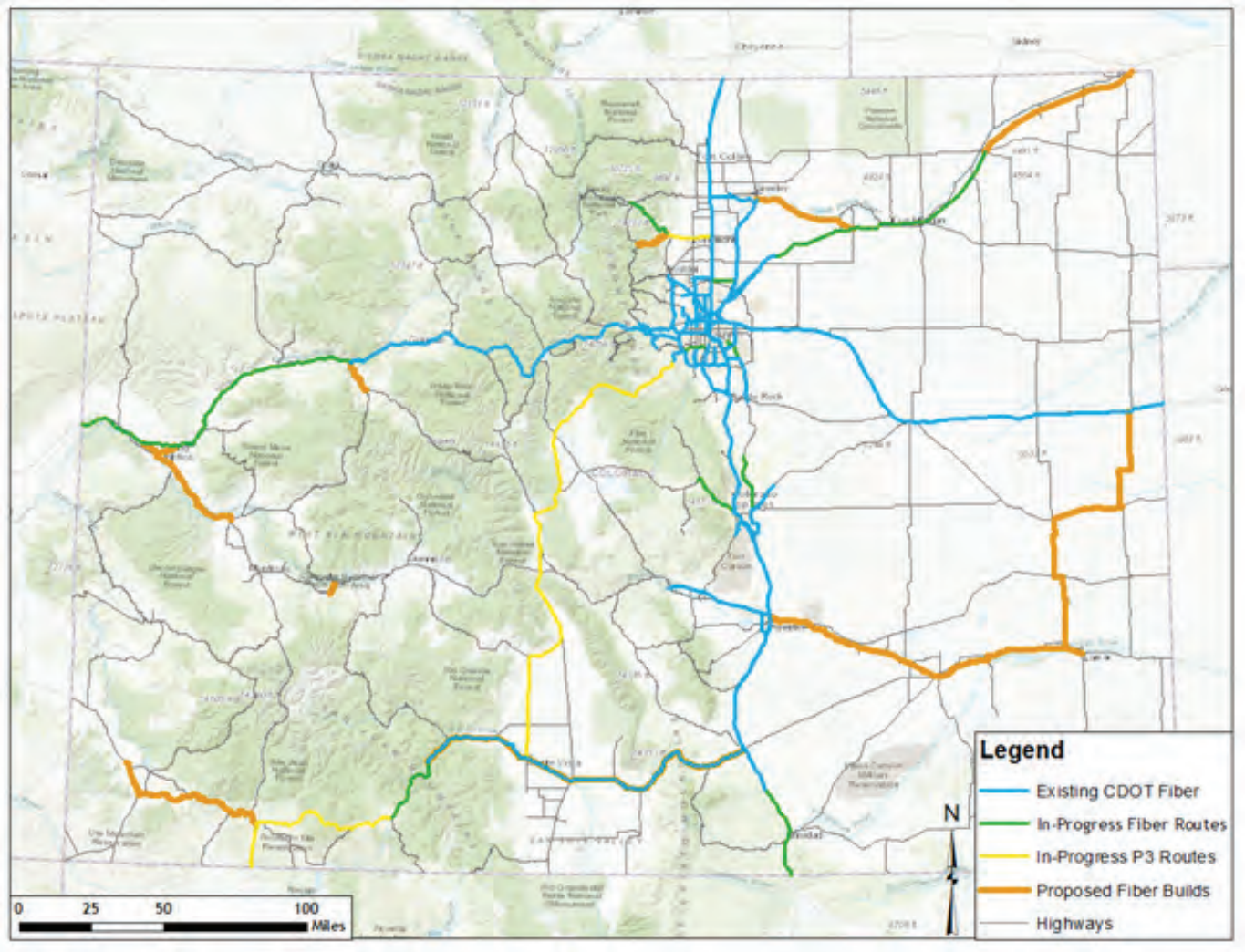
The ITS Branch does not plan or deliver new ITS devices. The ITS Branch assists with new construction projects by helping traffic planners and capital-project planners understand how to best deploy ITS technology and assets in such projects. CDOT's project-system engineering analysis process has been updated to require the evaluation of technology issues including longevity and responsibilities for power and software. This better positions CDOT to manage ITS assets after construction.

A planning effort led by the ITS Branch is expansion of the core fiber network (see **Figure A.5-4**). CDOT's primary fiber strategy has been to deploy fiber along all Interstate routes. The Department will reach the northern, western, eastern, and southern borders of the state with current fiber projects and aims to reach the northeastern corner of Colorado on Interstate 70 in a proposed project. Future strategic planning will identify corridors that can provide physical redundancy to Interstate corridors. This will increase the resiliency and reliability of CDOT's communication network.

Expansion of the fiber network through highway construction projects or standalone fiber-only projects in the coming years will improve situational awareness, operations, and safety on several rural and freight corridors. Fiber projects will also leverage existing opportunities for public-private partnerships (P3s), complete several traffic and maintenance goals for the Regions, and address ITS disaster-recovery initiatives.

Projects within communities that have little to no broadband services can improve equitable access and provide broadband resiliencies throughout the state.

Figure A.5-4 *Fiber Network Expansion Plan*



The types of ITS asset-management treatments undertaken by CDOT are linked to FHWA Work Types in **Table A.5-4** below.

Table A.5-4 *ITS Life-Cycle Management Activities*

Work Type	Activities
Preservation/Preventive Maintenance	» Work that is preventive in nature and keeps devices functioning by proactively performing routine tasks that prolong asset life. » For primary service-package components, examples include: – Annual preventive maintenance or calibration of sidefire radars, weather stations, dynamic message signs, lane-usage signs, and variable tolling signs. – Splice audits or field-data collection of fiber cable. – Landscaping, monthly cleaning of nodes or data centers. » For secondary components, examples include: – Field-data collection for power copper lines. – Preventive maintenance of power HVAC units.
Maintenance	» Day-to-day tasks that are reactive to roadway conditions or activities near the ITS asset. Examples include: – Pre- and post-storm cleaning of cameras. – Locates of fiber cable. – Rodent control at nodes or data centers.
Rehabilitation	» All tasks associated with troubleshooting an ITS asset that is "down" or malfunctioning. Examples include: – Troubleshooting and repairing camera malfunctions. – Sensor replacements at weather stations. – Splicing of fiber cable.
Reconstruction	» Major tasks related to emergency outages, damages, or repairs. Examples include emergency and extraordinary repairs of fiber cable.
Replacement	» Proactively replacing an existing asset based on useful-life reporting and planned replacement projects.
Initial Construction	» Any activity that grows the ITS asset inventory.

PROJECT SELECTION AND DELIVERY

The work types conducted by ITS asset managers are predominantly preservation, maintenance, repair, and reconstruction or replacement.

To prioritize replacements, the ITS Branch compares AIMS model outputs and the replacement list received from each CDOT Region against the condition of a device requested for replacement, including age, expended life, and the functionality of the devices. Functionality assessments consider whether an asset is functionally obsolete (e.g. not supported by the CDOT ATMS system). If a device is past its useful life but functioning properly it wouldn't be the highest priority to replace.

Prioritization decisions are evolving to consider the relationships between assets or components and the service packages they support. For replacement and new device requests, the following factors are also currently considered: traffic issues and the potential results of implementing the device, requested project cost, available funds, need, and anticipated benefits. Additional considerations for selecting ITS projects or strategies include guidelines under federal transportation legislation (e.g., MAP 21 and the FAST Act) and CDOT policies and objectives.

The ITS Branch has begun documenting information to support decisions and timing of asset replacements, repairs, relocations or removals. Such decisions may be based on purpose (service package), use, reliability, and cost estimation.

RISK MANAGEMENT

The ITS Branch helps manage risk across multiple levels—agency, programmatic, and project or asset. Section 6 of the TAMP provides more information about CDOT's risk-management methodology and processes, including an explanation of elements comprising risk scores.

RISK REGISTER

CDOT's ITS program maintains a register of risks to its program and projects. Top risks are shown in **Table A.5-5**.

Table A.5-5 *Top ITS Assets Risks*

Risk Level	Threat	Risk Score[5]	Risk-Management Strategy
Project	Vehicle strikes to ITS assets (e.g., variable message signs, signals, etc.)	150.0 (T)5 x (C)15 x (V)2	Treat by location, tolerate—repair, replace, collect damages
Project	ITS or traffic-control device failures, which can result in safety impacts	110 (T)5 x (C)11 x (V)2	Tolerate and respond
Project	Flood in a server room or field equipment building, losing control of ITS devices, with no center-to-center ops redundancy	106.2 (T)3 x (C)11.8 x (V)3	Treat, use sensors in the floor, or tolerate

5 Risk Score = Threat Likelihood (T) * Total Consequence and Consideration Score (C) * Vulnerability (V)

FINANCIAL PLAN

CDOT sets planning budgets for its asset classes four years in advance. The plan below assumes that asset-management funding for the ITS asset class will remain static for the foreseeable future, at the level set for fiscal 2027 ($16.6 million, including $1 million for planned device replacement). These budget assumptions, combined with CDOT's life-cycle management approaches discussed in the subsequent section, inform the investment strategies for ITS that CDOT plans to leverage to achieve system-wide asset performance goals while minimizing life-cycle costs.

FUNDING SOURCES

The ITS asset management program supports the life-cycle management and treatment needs (e.g., maintenance, replacement, etc.) for ITS assets. ITS asset management funding is separated into three areas:

- Agency operations which covers items like software and utility bills.
- ITS maintenance for day-to-day maintenance and emergency or extraordinary repairs.
- Capital replacement which is used for proactive replacements before more costly repairs are required. This makes up a relatively small portion of the overall budget.

ITS also utilizes other funding sources outside asset management:

- Most device replacements occur as part of roadway-reconstruction projects. The ITS branch seeks to collaborate with other asset managers and incorporate ITS needs into "bundled" projects for other asset classes, such as tunnels and signals. This may reduce disruption to travel and reduce costs as traffic control and other expenses can be shared.
- Expansion projects are funded through sources outside of the program.

PLANNED FUNDING

The 10-Year Financial Plan for ITS is shown in **Table A.5-6.**

Table A.5-6 *Financial Plan for ITS Assets (in millions)*

Funding Type	FY22	FY23	FY24	FY25	FY26	FY27	FY28	FY29	FY30	FY31
Capital Replacement	$4.8	$0.0	$0.0	$1.0	$1.0	$1.0	$1.0	$1.0	$1.0	$1.0
ITS Maintenance	$10.2	$16.2	$15.6	$16.6	$16.6	$16.6	$16.6	$16.6	$16.6	$16.6

INVESTMENT STRATEGIES

CDOT forms investment strategies based on its financial plan and life-cycle management strategies to achieve system-wide asset performance goals while minimizing life-cycle costs. The investment strategies delineate different types of work to be performed across CDOT's ITS assets over a 10-year period.

HOW INVESTMENT STRATEGIES ARE DETERMINED

The Department's investment strategies are informed by the AIMS model. The AIMS model only considers asset management capital replacement funding and treatment options. ITS maintenance is considered within the model through the deterioration assumptions included in the model. Each year, the current ITS inventory and age data are loaded into the AIMS model, and a suggested treatment list is generated to maximize the benefit for any given budget.

PLANNED INVESTMENTS

Asset Management Replacement Projects—As noted earlier, funds for device replacement are limited in the near term. An average of about $1 million per year is planned for proactive asset replacements annually during the time horizon of this TAMP. While the replacement cost of individual ITS assets can exceed $300,000, most ITS assets are relatively low cost, with the majority being less than $10,000. Some low-cost assets have relatively short useful lives, and some equipment may be replaced more than once during the period of the Financial Plan.

Major ITS System Project Investments—These investments are funded outside the asset management program.

EISENHOWER-JOHNSON MEMORIAL TUNNEL TECHNOLOGY UPGRADE

This $4.8 million project will upgrade ITS technology, such as cameras, lane-use signs, variable-message signs, and Ethernet equipment in this critical tunnel.

ITS CAMERA AND FIBER INSTALLATIONS STATEWIDE

This $9 million initiative will install cameras on I-25 South, I-76 in Region 4, and US-85 north of Denver.

VARIABLE-MESSAGE SIGN INSTALLATIONS

This $1 million initiative will install variable-message signs on SH-74 in Evergreen and EB US-285 near Conifer.

PERFORMANCE GAP ANALYSIS

CDOT uses its AIMS model each year to forecast the performance of ITS assets and any anticipated performance gaps. The results of this analysis inform the financial plan and investment strategies. The Department's ability to close performance gaps largely depends on receiving additional funding.

NEEDS AND PROJECTED CONDITION

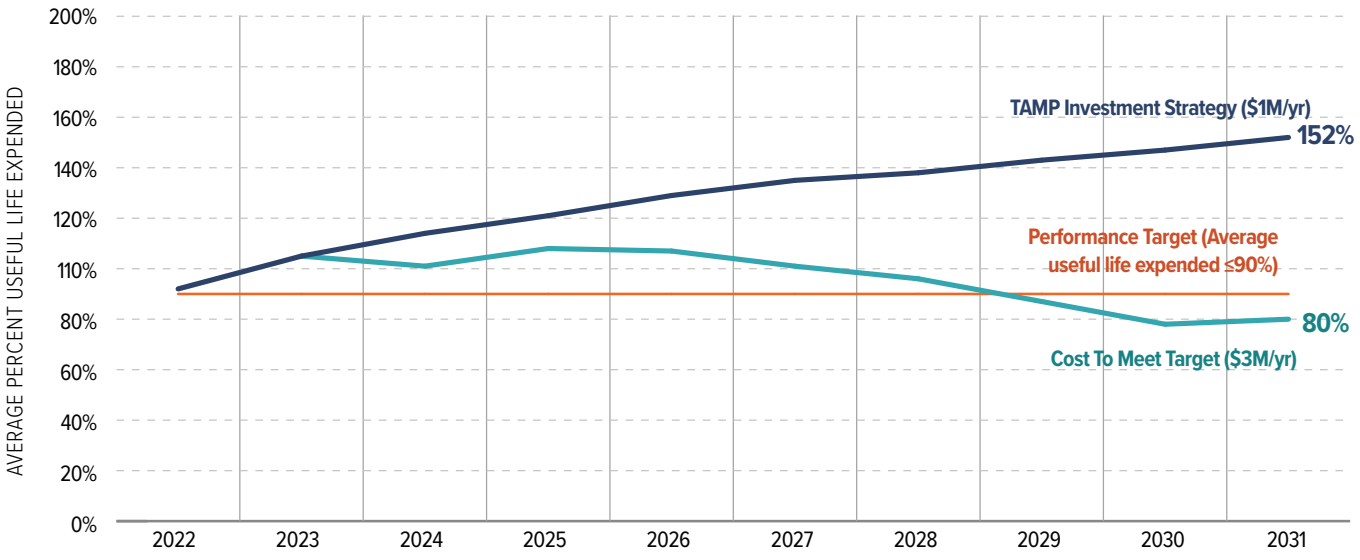
CDOT's AIMS model forecasts the long-term performance of ITS assets, constrained by anticipated annual budgets. The Percent of Expended Life is deteriorated using straight-line deterioration, based on age and expected life. For example, a device regardless of age, would deteriorate 20% per year.

Planned investments will provide about $1 million annually for proactive replacements over the next 10 years, which is insufficient to meet the PD 14.0 performance target. An increase of about $2 million annually beginning in 2023 would bring the ITS asset class back within its target state-of-good-repair and sustain it through 2031.

Figure A.5-5 shows the average percent of life expended for CDOT's ITS assets, as projected over time using planned funding levels. Under these amounts, ITS assets are projected to quickly begin missing the performance target of average expended life at or below 90%.

Figure A.5-5 *Projected Performance of ITS Assets Over Time*

The anticipated annual budget of $1 million for proactive device replacement will not meet the performance target of ensuring that the average percent of useful life expended is at or below 90 percent. The annual cost of meeting the target by 2031 is about $3 million, or an additional $2 million per year.



*Target is less than 90% of useful life expended

PERFORMANCE IMPACTS OF INSUFFICIENT FUNDING

Funding shortfalls for ITS assets can increase the likelihood of malfunctions that compromise the reliability of ITS devices, such as variable-message signs. Insufficient funding also can lead to malfunctioning technology in CDOT's operations centers, or to inaccurate fiber inventories that increase accidental fiber cuts and damage. In sum, an underfunded, less reliable network can reduce safety and mobility and increase future costs.

OPPORTUNITIES TO CLOSE THE GAP

Limited opportunities exist to significantly close the anticipated performance gap besides additional funding. In the short run, funding shortfalls may be somewhat mitigated by technology deployments in capital-construction projects, improving utility-account management, and increasing the accuracy of the ITS asset inventory. Improved inventories and performance reporting can enable more robust management of the ITS asset class.

STRATEGIC USE OF ADDITIONAL REVENUE

Should CDOT receive additional revenue to fund the ITS asset class, the Department's first priority is to eliminate any funding gaps related to achieving the PD 14.0 performance target. Once goals are achieved, the Department will reduce Poor backlog with a priority towards the most critical and/or vulnerable assets to improve system resilience. CDOT estimates the current "Poor" backlog for ITS could be eliminated with about $20 million.

FUTURE IMPROVEMENTS

Planned improvements to ITS asset management address processes, technology, and staff.

PROCESS AND ANALYSIS IMPROVEMENTS

ITS asset managers are focused on continued process improvements. A foundation for these improvements is a more complete asset inventory. To that end, the ITS Branch intends to bring the following assets into its management system:

- ITS assets in the Eisenhower-Johnson Memorial Tunnel, which are being replaced through calendar 2022.
- Cabinets and switches on traffic signals.

Other areas of improvement include Systems Engineering Analysis (SEA) and ITS Architecture, and better performance reporting and planning for ITS Assets.

SYSTEM ENGINEERING ANALYSIS AND ITS ARCHITECTURE

As CDOT establishes the architecture for how assets communicate with each other (service packages), both installation and maintenance activities will become more efficient. For new construction, planners will be able to choose from a series of packages based on intended functionality, rather than deciding on individual assets in isolation.

As CDOT moves increasingly into managing ITS assets by service packages, a metric that measures the availability of systems (MTTR) and Service Level Agreements will assume greater importance in assessing performance.

BETTER PERFORMANCE REPORTING AND PLANNING

CDOT's ITS program is planning to implement new project-delivery processes to ensure technology is integrated thoughtfully. The program is also improving the architecture and inventory of deployed service packages for better tracking and for forecasting service impacts from device failures.

Currently, asset replacement is prioritized by age. In the future, replacements will be based on the reliability of the service packages that CDOT delivers and the risk of components failing, as differentiated by the function being served.

TECHNOLOGY IMPROVEMENTS

Planned technology improvements will focus on better integrating CDOT's GIS tools with its SAP financial system, avoiding duplication of inventory information and facilitating management of work orders.

STAFF IMPROVEMENTS

ITS is focusing on internal training and documentation to increase role redundancy, which will increase resiliency. Many ITS staff are experts on distinct components of the ITS system. The ITS program aims for staff to have colleagues who can act as backups in emergencies. This will require revisiting position descriptions and reference documentation within the branch and focusing on consistency and clarity in documentation and training.

A-6. MAINTENANCE LEVELS OF SERVICE (MLOS)

Maintenance plays a critical role in CDOT's Transportation Asset Management (TAM) program. Maintenance Levels of Service (MLOS), considered an asset class within the program, provides preservation and maintenance services for pavement, bridges, culverts and many other assets managed by other programs. In addition, MLOS manages the life cycle of many safety- and traffic-related assets, such as signs, pavement markings, and roadway lights. Finally, MLOS provides major operational services, notably snow and ice removal from roadways, as well as mowing, noxious weed and vegetation control, and right-of-way landscaping.

Figure A.6-1 presents types of traffic and safety assets that MLOS maintains.

Figure A.6-1 *MLOS Assets at a Glance*

MLOS is the budget category for CDOT's Maintenance program, managed by the Division of Maintenance and Operations (DMO), which provides a broad range of asset maintenance and other services. The term "MLOS" also is used at times to refer to the actual maintenance program and its services. Through its maintenance services, MLOS contributes to improved safety and mobility for the traveling public and ensures that CDOT maximizes the value of its highway assets. When the need for premature asset rehabilitation and replacement is reduced, life-cycle costs are lower.

The Information Management Services Branch, part of CDOT's Division of Maintenance and Operations, develops and manages procedures and guidance for the MLOS program and maintains operational oversight for program administration.

There are nine MLOS Maintenance Program Areas (MPAs):

- Snow and Ice Removal—Snow removal and avalanche mitigation.
- Roadway Surface—Pothole filling, chip seals, paving, patching, etc.
- Roadside Facilities—Ditches/ streambeds cleaning, litter removal, rockslide response/cleanup, etc.
- Roadside Appearance—Mowing and weeding.
- Traffic Services—Striping, signs, guardrails, signals, roadway lighting, etc.
- Structure Maintenance—Bridge repair and maintenance.
- Equipment and Grounds—Rest areas, buildings, and equipment maintenance.
- Tunnel Maintenance—Repairs, monitoring, and maintenance.
- Planning/Training—Administration and employee training/certification.

PERFORMANCE MANAGEMENT

Performance of the maintenance program is monitored and managed as part of CDOT's performance management framework through quantitative measures and targets. These metrics inform funding decisions and track how well the program is supporting the Department's strategic goals and transportation services.

POLICY DIRECTIVE 14.0 PERFORMANCE MEASURES

The asset management program for maintenance contributes to several goal areas in Policy Directive 14.0 (PD 14.0)—asset management, safety, and mobility. The routine maintenance activities provided by the program help assets function and perform as intended throughout their life cycle. PD 14.0 includes a specific performance measure for overall Maintenance Levels of Service (MLOS), as well as for Snow and Ice Removal. Activities performed by the maintenance program support the function of highway assets managed by several units at CDOT, including assets entirely managed by the maintenance program itself. These activities provide the maintenance and services needed to keep road users safe. The activities include maintaining street striping, signs, guardrails, and roadway lighting, and removing snow and ice. Maintenance operations enhance mobility by providing maintenance and other services that keep road surfaces safe and navigable. On average, CDOT plows snow on over six million lane miles each year.

The PD 14.0 performance measure for MLOS is assessed using a report-card system of grading in which six of the nine Maintenance Program Areas (MPAs) are each given a grade. The following MPAs are considered performance-based, and are therefore used to determine an overall MLOS grade:

- Snow and Ice Removal—Snow removal and avalanche mitigation.
- Roadway Surface—Pothole filling, chip seals, paving, patching, etc.
- Roadside Facilities—Ditches/streambeds cleaning, litter, rockslide response/cleanup, etc.
- Roadside Appearance—Mowing and weeding.
- Traffic Services—Striping, signs, guardrails, signals, roadway lighting, etc.
- Structure Maintenance—Bridge repair and maintenance.

The remaining three MPAs are excluded from the overall MLOS grade because of the difficulty in developing an objective way to measure performance.

CDOT considers a letter grade of B- for maintenance of assets for which MLOS has partial life-cycle management responsibility to be a state of good repair. The goal for Snow and Ice Removal is a letter grade of B. Snow and Ice Removal, with its substantial impact on safety and mobility, is the largest expenditure category within MLOS.

Table A.6-1 shows the PD 14.0 targets and 2021 performance for MLOS.

Table A.6-1 *CDOT Asset Management Metric and Performance Target for MLOS*

Measure	Target	2021 Performance
Maintenance Levels of Service for the State Highway System	B-	C-
Level of Service for Snow and Ice Removal	B	C-

OTHER PERFORMANCE MEASURES

The metric for each Maintenance Program Area (MPA) is specific to each asset within each area. For example, the grading criteria for metal guardrails and cable rails, which are both within the Traffic Services MPA, are shown in **Table A.6-2**.

Table A.6-2 *Level of Service Criteria for Metal Guardrail and Cable Rail*

Level of Service Grade	Percent Deficient (Metal Guardrail)	Percent Deficient (Cable Rail)
A	0.0 - 2.5	0.0 - 0.5
B	2.5 - 5.0	0.5 - 1.0
C	5.0 - 10	1.0 - 3.0
D	10 - 15	3.0 - 5.0
F	>15	>5.0

For Snow and Ice Removal, assessment of performance includes “time to bare pavement” and avalanche control.

Several work units within CDOT contribute condition data used to determine MLOS performance grades. These units include Staff Bridge, Pavement Management, Property Management, and Traffic Safety. Surveys completed by maintenance employees also are used.

INVENTORY AND CONDITION

The Division of Maintenance and Operations takes a proactive approach to documenting and maintaining an accurate and up-to-date asset inventory, and to making such data accessible and historically continuous.

INVENTORY

The MLOS asset inventory resides in an ESRI database and is used in Maintenance's Work Manager software system. The inventory is shown in **Table A.6-3**.

Table A.6-3 *Safety- and Traffic-Related Maintenance Assets*

Asset Type	Count
Metal Guardrail (linear feet)	6,911,813
Concrete Guardrail (linear feet)	2,581,538
Cable Guardrail (linear feet)	838,727
Signs	211,738
Striping (miles)	48,928
Pavement Markings	34,735
High-Mast Lighting	752
Roadway Lighting (Light Poles count)	26,984
Crash/Energy Attenuators	22,878
End Treatments	23,427
Delineators	493,000
Fence (linear feet)	58,462,326

Figure A.6-2 *Examples of MLOS Assets*

Table A.6-4 shows asset classes for which MLOS only has maintenance responsibilities. These assets are the subject of separate asset plans, which describe the systems in which the data resides for each asset class. Maintenance keeps a duplicate inventory of all assets that it maintains in the Maintenance ESRI database and Work Manager system.

Table A.6-4 *Assets for which MLOS has Maintenance Responsibilities*

Asset Class	Asset Type	Count
Pavement	Lane Miles of Pavement	23,016
Bridges	Bridges	3,464
Culverts	Culverts	5,946
Walls	Noise Walls	357
Signals	Traffic Signals	1,843
Buildings	Employee Housing Units	93
Rest Areas	Rest Areas and Ancillary Structures	140
Tunnels	Staffed and Unstaffed Tunnels	20
ITS	Devices, Network Gear, Fiber Cable Miles, Facilities	5,333
Fleet	Rolling Stock	3,123

CONDITION

Maintenance performance is measured by levels-of-service grades. These grades are aggregated to the Maintenance Program Areas (MPA) level and then to a statewide grade for MLOS.

In FY 2021, MLOS achieved a grade of C-. This grade is below CDOT's B- target and represents a deterioration from recent years, when MLOS achieved a B.

For traffic- and safety-related assets for which MLOS has overall management responsibility, and which generally fall within the Traffic Services MPA, the MLOS grade measures asset condition. (The same is true for fencing, which falls within the Roadside Facilities MPA along with other roadside assets for which MLOS only has maintenance responsibility.) In 2021, the MLOS letter grade for the Traffic Services MPA was D+. **Table A.6-5** describes the grading scale for Traffic Services' cable rail.

For those assets for which MLOS provides maintenance services, but has no life-cycle management responsibilities beyond maintenance, the MLOS letter grade represents an aspect of asset condition. The condition of those assets is described in their respective asset plans. An example of how the maintenance levels for such assets is assessed is shown in **Table A.6-6**.

Table A.6-5 *Example of MLOS Grading Scale for Traffic Services, Cable Rail*

***Performance Metric:** Cable rail is deficient if posts are bent or damaged, have buildup, or there is slack in the ropes between posts. The number of feet of deficient cable rail is measured and is compared to the total measure of cable rail in the sample area.*

Grade	Condition Description
A	Cable rail with less than .5% of damage.
B	Cable rail with damage between .5% and 1%.
C	Cable rail with damage between 1% and 3%.
D	Cable rail with damage between 3% and 5%.
F	Cable rail with damage greater than 5%. If an anchor is damaged, even if it is outside of the sample area, the entire cable rail is considered deficient.

Table A.6-6 *Example of MLOS Grading Scale for Culverts*

***Performance Metric:** These assets are graded by the percentage of inlets and outlets that are blocked.*

Grade	Condition Description
A	Silt accumulation is less than 2%.
B	Silt accumulation is between 2% and less than 5%.
C	Silt accumulation is between 5% and less than 10%.
D	Silt accumulation is between 10% and less than 20%.
F	Silt accumulation is greater than 20%.

Source: Highway Maintenance Levels of Service Manual

LIFE-CYCLE PLANNING

Life-cycle planning responsibilities for MLOS are limited to traffic- and safety-related assets and include reactive and interval/age-based approaches. The Information Management Services Branch, part of CDOT's Division of Maintenance and Operations, develops and manages procedures and guidance for the MLOS program and maintains operational oversight for program administration.

LIFE-CYCLE PLANNING

While MLOS maintains a wide variety of assets, its life-cycle planning responsibilities are limited to traffic and safety-related assets not managed by other asset classes.

Both reactive and interval/age-based life-cycle management approaches are used for different types of assets. For example, when damage is observed, individual signs and guardrails are repaired by the responsible maintenance patrol. On the other hand, Traffic personnel track replacement cycles and life cycles of signs and striping and program MLOS funds for replacement at the end of the life cycle.

PROGRAM DECISION-MAKING

The Information Management Services Branch maintains operational oversight for MLOS program administration, including development and implementation of procedures and guidance.

CDOT's Manual of Maintenance Procedures outlines the procedures performed by maintenance personnel.

HEADQUARTERS AND REGION ROLES

The MLOS maintenance and repair program for safety- and traffic-related assets is managed by the Region Traffic Operations sections, with some assets being repaired by local Maintenance Patrols.

TREATMENT SELECTION

The following subsections provide examples of treatments MLOS performs.

Preservation/Maintenance and Repair: Maintenance and Traffic personnel perform preventive maintenance and repair for most highway assets. Maintenance staff repair and replace most assets on CDOT roadways. Traffic staff focus on specific traffic-related assets

such as multi-post signs, striping, pavement markings, traffic signals, cameras, etc. When the needed repairs exceed funding levels, assets are prioritized based on condition and safety/operations benefits.

A significant portion of the work is performed by in-house crews, and some is performed by contractors through the procurement and contracting processes.

Work related to signals follows statewide guidance on signal preventive maintenance established by the Traffic sections.

A more detailed description of the types of maintenance and repair to traffic-related assets can be found in the Manual of Maintenance Procedures.

Aside from traffic-related assets, MLOS also performs preventive maintenance and repairs for rest areas and maintenance buildings. These treatments may address the appearance of exterior and interior walls and finishes, the functioning of interior utilities and fixtures, and the condition of the pavement and pavement markings on the grounds around these facilities.

Replacement: MLOS performs replacement activities for traffic- and safety-related assets under the Traffic Services MPA, as well as fencing under the Roadside Facilities MPA. Signs, striping, and pavement markings are replaced on a rotating basis to maintain minimum reflectivity levels. Maintenance workers inspect these assets visually at least four times a year. The Traffic section tracks replacement cycles and life cycles of striping and signs and programs MLOS funds for replacement at the end of their life cycle. For striping, useful life is location-dependent, and the Traffic sections determine the appropriate replacement cycle for each Region.

The FHWA Manual on Uniform Traffic Control Devices for Streets and Highways (MUTCD) has minimum standards for sign and striping retroreflectivity.

Rehabilitation/New Construction: These work types are not undertaken by MLOS. Impact to MLOS is not currently taken into consideration when new capital projects are planned and/or executed.

RISK MANAGEMENT

MLOS maintains a register of risks at the program and project level. Section 6 of the main TAMP document provides more information about CDOT's risk-management methodology and processes.

The top MLOS risks are shown in **Table A.6-7**.

Table A.6-7 *Top MLOS Program Risks (2022)*

Risk Level	Threat/ Opportunity	Risk Score[1]	Risk-Management Strategy
Project	Burn areas produce post-fire debris flows, blocked culverts, loss of service.	21.0 (T)5 x (C)4.2 x (V)1	Monitoring and preventive maintenance
Project	Culverts less than 48-inch diameter failing and closing road.	16.0 (T)5 x (C)3.2 x (V)1	Inspection and repair
Project	Hazardous materials spill.	16.0 (T)5 x (C)3.2 x (V)1	Tolerate and respond

1 Risk Score = Threat Likelihood (T) * Total Consequence and Consideration Score (C) * Vulnerability (V)

FINANCIAL PLAN

CDOT typically represents MLOS funding as part of the Transportation Asset Management program budget. For fiscal year 2026 and beyond, however, MLOS planning budgets will no longer be set in conjunction with other asset classes. Instead, MLOS budgets will be determined closer to the year in which services are delivered to better reflect labor costs, materials costs, and other factors.

PLANNED FUNDING

The 10-year financial plan for MLOS is shown in **Table A.6-8**. For the first four years of this TAMP period, these amounts have been set in "planning budgets" approved by the Transportation Commission. Beyond FY 2025, the table shows illustrative budget levels based on a 3 percent increase every year to account for inflation.

Table A.6-8 *Financial Plan for MLOS (in Millions)*

FY22	FY23	FY24	FY25	FY26	FY27	FY28	FY29	FY30	FY31
$263.5	$267.8	$269.0	$269.0	$277.0	$285.0	$294.0	$303.0	$312.0	$321.0

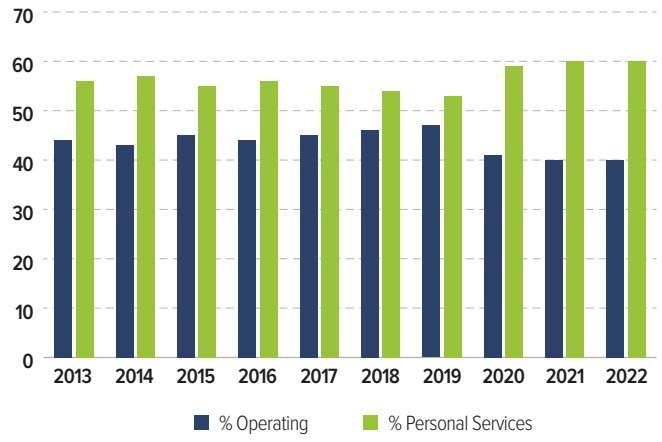
INVESTMENT STRATEGIES

CDOT strategically invests in maintenance areas of critical importance. The Department devotes well over half of its maintenance budget to its two largest Maintenance Program Areas: Snow and Ice Control and Traffic Services. Traffic Services includes life-cycle responsibility for a range of assets including signs and striping. Despite high costs, snow and ice removal is critical to safe and reliable travel across the state, and safe roadway conditions help preserve the state of good repair of roadway assets.

BACKGROUND: DETERMINING INVESTMENT STRATEGIES

The maintenance program in recent years has experienced sharp increases in wage and benefit costs, as well as materials costs rising at faster rates than annual budgets. The proportion of the MLOS budget allocated to personal services, such as salaries and benefits, has been growing, as shown in **Figure A.6-3**. Personal services now consume 60 percent of the MLOS budget, while 40 percent is consumed by operating expenses.

Figure A.6-3 *Personal Services vs. Operating Costs in the MLOS Budget*

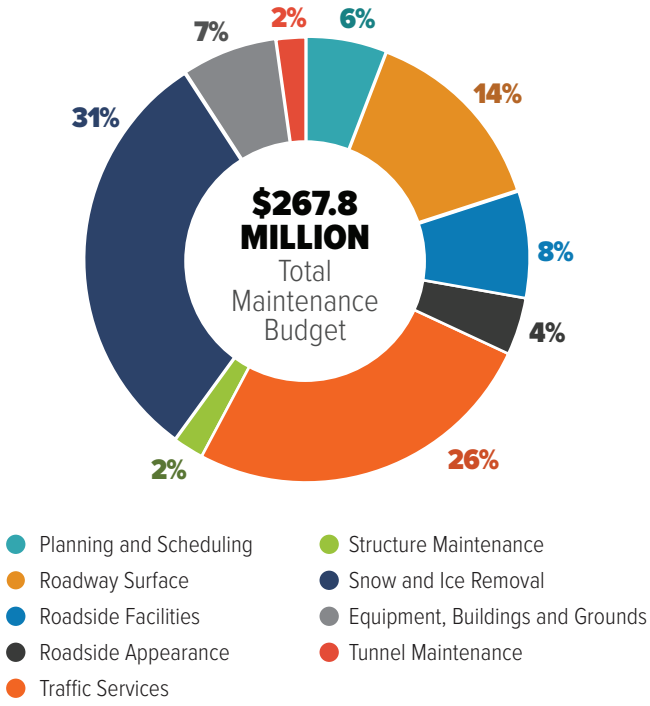


PLANNED INVESTMENTS

Maintenance budgets are not expected to increase significantly in the next 10 years. In this scenario, snow and ice control—one of the most critical maintenance activities in Colorado—will consume a larger share of the budget. Other investments are likely to continue at somewhat reduced levels in approximately the same proportions and amounts as current investments.

Figure A.6-4 shows the planned allocation of available financial resources among the nine MPAs for FY 2023.

Figure A.6-4 *Maintenance Program Areas FY 2023 Budgets*



PERFORMANCE GAP ANALYSIS

The MLOS program forecasts long-term maintenance performance given various budget scenarios, so that the impacts of funding levels on service levels can be evaluated. Spending at levels shown in the Financial Plan is predicted to result in MLOS falling below its performance target.

PROJECTED CONDITION UNDER DIFFERENT BUDGET SCENARIOS

The cost to achieve CDOT's target of a B- for MLOS over the next 10 years is more than expected funding. The forecasted shortfall is about $838 million over 10 years, or $83.8 million per year.

Figure A.6-5 shows the cost to achieve CDOT's Level of Service objective for MLOS along with planned funding levels.

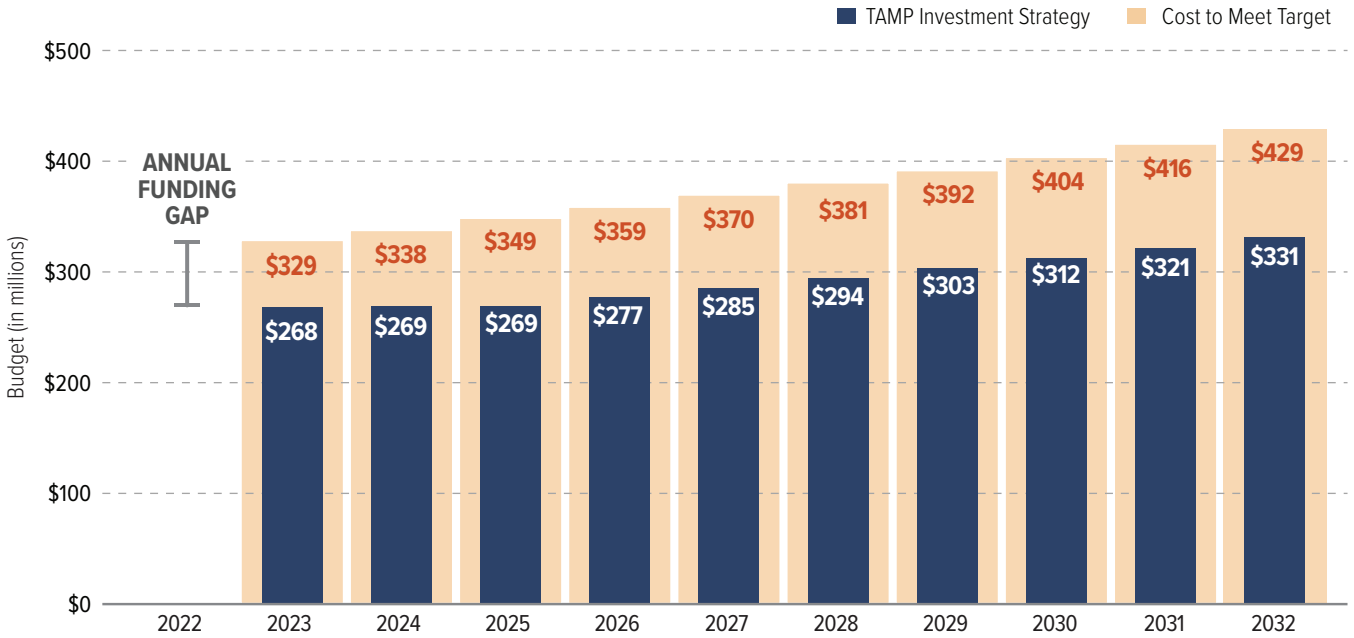
RISKS OF INSUFFICIENT FUNDING AND PERFORMANCE IMPACTS

Because CDOT places highest priority on snow and ice removal in the MLOS program, funding shortfalls are expected to have the greatest impact on other maintenance services and assets. Insufficient funding carries various risks, including:

- **Life-Cycle Risk:** Insufficient maintenance leads to underperforming assets that can cause service disruptions and premature asset failure. Deterioration rates for other assets where MLOS provides preservation/maintenance actions will not perform as predicted if maintenance is reduced.

Figure A.6-5 *Projected Budgets versus Costs to Meet MLOS Performance Target (in millions)*

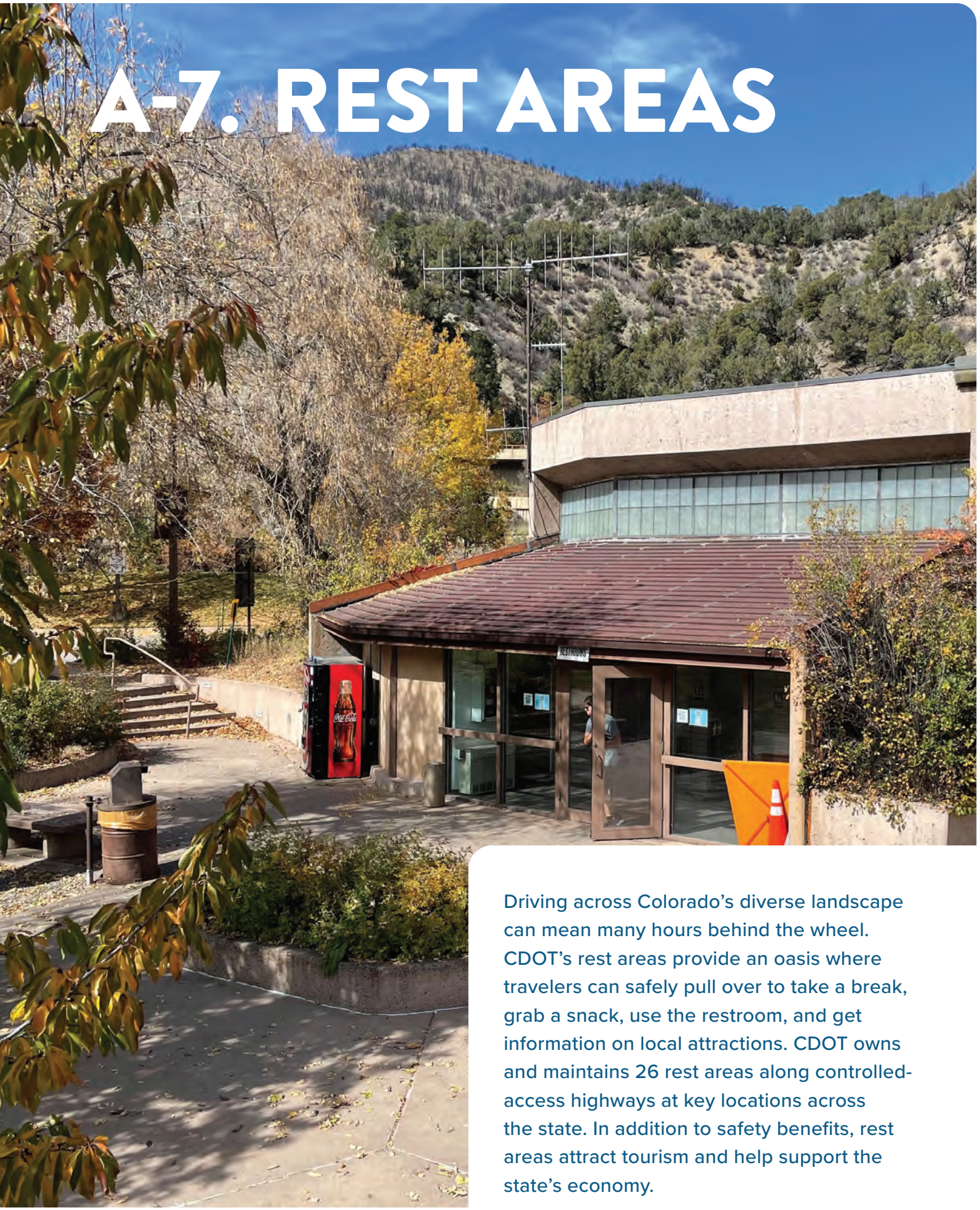
The anticipated annual budget will not meet the performance target of a B- grade or better for MLOS. The additional cost of meeting the target is an average of about $83.8 million per year.



- **Fiscal Risks:** Underfunding maintenance can increase costs by shortening the life of assets, and increasing corrective-maintenance needs, service interruptions, and failures.
- **Public Perception Risks:** Deferred maintenance contributes to safety hazards and energy inefficiency and may negatively affect how the public views CDOT's stewardship of the highway system.

While the cost of living in Colorado has increased significantly in recent years, compensation for all state employees has not kept pace. Similarly, the MLOS budget has not increased sufficiently to cover pay increases and rising materials costs, and the percentage of the budget dedicated to personal services versus operating costs has shifted. The personal services budget funds labor and benefits, while the operating budget funds materials such as deicing materials and asphalt. The Division of Maintenance and Operations has determined the MLOS budget should maintain a 50/50 split between personal services and operating budgets to ensure appropriate services levels are maintained. Maintaining this split will require an increase in planned MLOS budgets.

A-7. REST AREAS



Driving across Colorado's diverse landscape can mean many hours behind the wheel. CDOT's rest areas provide an oasis where travelers can safely pull over to take a break, grab a snack, use the restroom, and get information on local attractions. CDOT owns and maintains 26 rest areas along controlled-access highways at key locations across the state. In addition to safety benefits, rest areas attract tourism and help support the state's economy.

CDOT's rest areas are managed in alignment with the asset-management process described in the Introduction to the Asset Plan Appendix. Currently, 63 percent of rest areas have a condition grade of C or better—short of CDOT's 90 percent target. An additional annual investment of at least $5 million beyond current funding would be required to achieve the target in the next 10 years.

Figure A.7-1 *Rest Area Assets at a Glance*

PERFORMANCE MANAGEMENT

The performance of rest areas is monitored and managed as part of CDOT's Rest Area Property Management program through quantitative measures and an overall target. The measures and target inform funding decisions and track how these assets are supporting the Department's strategic goals and the transportation services provided to the public.

POLICY DIRECTIVE 14.0 PERFORMANCE MEASURE

The asset management program for rest areas contributes to all Policy Directive 14.0 (PD 14.0) goal areas: asset management, safety, and mobility. The performance measure in PD 14.0 for rest areas is the percentage of assets with a C grade or better, on an A to F scale. The letter grade considers overall rest area condition through visual assessment of individual elements such as building structure; building exterior appearance, including the condition of grounds, pavement and pavement markings; building interior condition and appearance; and overall site and building compliance with the Americans with Disabilities Act (ADA). The process for assessing condition through assignment of letter grades is described in the Inventory and Condition section of this Rest Area Asset Plan. **Table A.7-1** presents the PD 14.0 target and 2021 performance for rest areas.

For federal TAMP purposes, CDOT defines state of good repair based on the measures presented in PD 14.0.

CDOT considers its rest areas to be in a state of good repair if 90 percent are assessed at grade C or better. The current (2021) percentage of rest areas assessed at a C or better is 63 percent—short of the target. The reason for this performance gap is described in Performance Gap Analysis section of this Rest Area Asset Plan. One criteria for achieving a C grade is meeting ADA requirements. It is expected that all rest areas will be ADA compliant by the end of FY 2024.

Table A.7-1 *CDOT Asset Management Metric and Performance Target for Rest Areas*

REST AREAS

Measure	Target	2021 Performance
Percentage of Rest Areas with a C grade or better	90%	63%

INVENTORY AND CONDITION

Dedicated CDOT staff assess the condition of each rest area annually with a letter grade based on multiple criteria, including structural integrity and overall site condition. The Department collects rest-area inventory and condition data using a mobile application and stores the data in its "buildings dashboard." The use of dedicated staff helps remove subjectivity in the evaluations, maintaining consistency across the assets. CDOT assesses the performance of its rest areas portfolio by the percentage of rest areas achieving a C grade or better, as described in the Performance Management section.

INVENTORY

As of 2022, CDOT owns 26 rest areas statewide, including 117 ancillary structures, as shown in **Table A.7-2**. Ancillary structures are located within rest-area locations and can include storage sheds and picnic shelters. The 26 rest areas are assessed as one grade each, combining all ancillary equipment into a single rating. Rest areas are classified in different tiers based on their purposes, as shown in **Table A.7-3.**

Table A.7-2 *Inventory of Rest Area Assets*

Asset Type	Tier 1	Tier 2	Tier 3	Count
Rest Areas	7	13	6	26
Ancillary Structures	42	58	17	117
Total	49	71	23	143

Table A.7-3 *Description and Examples of Rest Area Tiers*

	**Tier 1 rest areas provide the full range of amenities and services, including daily staffing. They are considered critically important, because they are located near key entrances to the state, its welcome centers and to Vail Pass.**
	**Tier 2 rest areas provide a medium range of services, including heat, potable water, flushable toilets, and maps and brochures about the state.**
	**Tier 3 rest areas provide access to basic services, such as vault or pit toilets, and have no running water or heat.**

A map illustrating the locations of CDOT rest areas is shown in **Figure A.7-2**. Rest areas are represented by a CDOT pin icon.

Figure A.7-2 *Rest Areas in CDOT's Building Inventory*

ASSET HIERARCHY

Table A.7-4 provides an overview of the different tiers of rest areas and the features and levels of service provided at each. To understand the performance of rest area assets, CDOT tracks the condition and functionality of the major features and facilities that comprise each rest area.

Table A.7-4 *Asset Hierarchy*

Rest Area Tiering	Tier 1 Critically Important	Tier 2 Above Average	Tier 3 Basic
Key Entrance to State or Vail Pass	Yes	No	No
Daily Staffing	Yes	No	No
Internet Service	Yes	No	No
Separate Parking for Cars and Trucks	Yes	No	No
Air Conditioning	Yes	No	No
Kiosk Info with Maps/Brochures	Extensive	Mid-Range	No
Cell Service	Yes	Yes	No
Heat	Yes	Yes	No
Paved Parking	Yes	Yes	No
Potable Water	Hot & Cold	Hot & Cold	No
Picnic Tables	Yes	Yes	Maybe
Flush Toilets	Yes	Yes	Vault or Pit

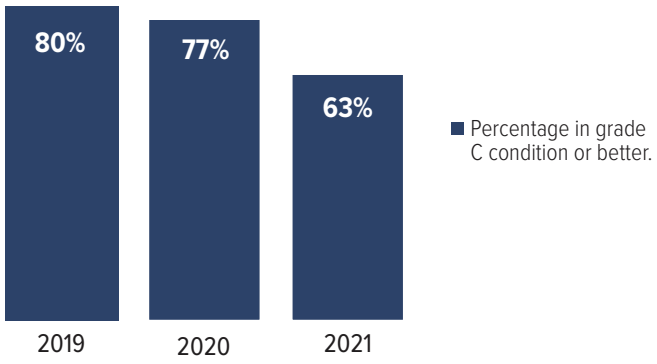
CONDITION

Rest area condition refers to the letter grade given to each rest area based on information gathered during the annual condition assessment. The assessment considers rest-area components by customized categories that are consistent with the rest area tiers. Rating elements include visual assessments of the condition of the building structure, building-exterior appearance, appearance of grounds, condition of pavement and pavement markings, building-interior cleanliness and appearance, and operation of utilities and fixtures. Rest areas are assigned a letter grade of A-F, as described in **Table A.7-5**.

CURRENT CONDITION AND HISTORICAL TRENDS

Sixty-three percent of CDOT's 143 rest areas and ancillary structures have been assessed at letter grade C or better condition, as presented in **Figure A.7-3**. Rest areas were established as part of CDOT's Transportation Asset Management (TAM) program in November 2018, and condition monitoring started in 2019. Deterioration has occurred since that time. Rest areas will be eligible for TAM program funding in FY 2023.

Figure A.7-3 *Rest Area Condition Trends*



ASSET VALUE

CDOT undertook an assessment of asset value in 2022 for this document. The current replacement value of rest areas is determined by using a unit cost for building square footage. This replacement value is $134 million.

Table A.7-5 *Definitions of Rest Area Letter Grades*

Letter Grade	Description
A	Most items are rated excellent or very good.
B	Most items are rated good or better with few or no serious deficiencies.
C	Most items are rated good or better with few serious deficiencies, with none in critical condition. The facility is ADA compliant.
D	Items are rated no higher than good, with some serious deficiencies, and a limited number of critical problems.
F	Items are rated no higher than good, with many in fair or poor condition, with serious or critical deficiencies.

LIFE-CYCLE PLANNING

CDOT analyzes its rest area inventory and inspection data to forecast investment needs and to set work priorities. This process is known as life-cycle planning and accounts for the whole-life costs of planning, constructing, and maintaining assets with consideration for minimizing cost while preserving or improving the condition. If a rest area is assigned a letter grade D or F, CDOT considers it for replacement, while rest areas with a letter grade C or better are considered for refurbishment. Planned treatments for rest areas are informed by findings from the annual condition assessment—as well as the recommendations from CDOT's asset model.

LIFE-CYCLE PLANNING

CDOT uses a condition-based approach to the life-cycle management of rest areas. This means condition data is used to determine the appropriate type and timing of work, and to prioritize potential work within available budgets. CDOT performs cost-benefit analysis via its AIMS model to determine the most cost-efficient treatment program. Based on the results from the cost-benefit analysis, CDOT identifies which rest area projects should be prioritized for treatment.

The AIMS modeling and analysis process generates strategies composed of one or more treatments over the analysis period.

In early 2022, the Property Management team refined the "useful life" estimates for all rest areas, based on construction type. The new estimates were used to modify deterioration assumptions in the AIMS model. In addition, an updated set of planned rest area projects were incorporated into the model assumptions. The model considers the following treatments for rest areas:

- Rest area refurbishment, which is triggered when the rest area letter grade is a "C."
- Rest area replacement, which is triggered when the rest area letter grade is a "D" or an "F."

This improved process will provide more specific recommendations that maximize budget allocations and provide more accurate modeling.

CDOT's Rest Area Property Management program leads efforts to rehabilitate and replace rest areas and provide controlled and deferred funds to each Maintenance Section to perform routine maintenance, preservation treatments, and repairs that do not require engineering. The Maintenance Levels of Service program covers costs for cleaning; and for refilling and replacing cleaning supplies, toilet paper, paper towels, and lightbulbs. Maintenance Levels of Service also pays for mowing, landscaping, plowing, and any other duties needed for day-to-day operation of the rest areas.

PROGRAM DECISION-MAKING

TREATMENT SELECTION

CDOT uses a number of treatments to address rest area deterioration. Rest area treatments can range from minor electrical repairs to roof replacements, to remodeling, to complete facility replacements. The treatment selected depends on the rest area condition and availability of funds. Definitions of rest-area treatment work types are summarized below. A list of rest area treatments and their typical costs are presented in **Table A.7-6**.

Controlled Maintenance: involves corrective repairs or improvements that increase the safety or operating efficiency of a building. These treatments are meant to prevent a building from slipping to a lower letter grade. Maintenance activities are necessary for health, life safety, and code compliance of A, B, and C-rated rest areas and fixed equipment necessary for the operation of rest areas. Examples include updating sinks or toilets to low-flow models or installing a new furnace. This, along with deferred maintenance, comprises about 15 percent of annual funds and includes cleaning and other preservation activities.

Deferred Maintenance: includes corrective repairs or improvements for rest areas with a D rating. These treatments are meant to elevate the overall rest area condition and prevent the rest area from falling to an F rating. Examples include replacing a roof or a minor remodel.

Rehabilitation: can include increases to the square footage, life expectancy, operating efficiency, or capacity that add value to land and rest areas. Costs for the design and construction of these improvements generally exceed $50,000, such as updating a sewage treatment system or a major remodel. These treatments increase life expectancy and improve operating efficiency.

Reconstruction: consists of replacement of an existing rest area on CDOT-owned land with a new rest area on the same land. It is usually the result of years of lack of funds for proper preservation and maintenance resulting in a rest area that is not able to be rehabilitated.

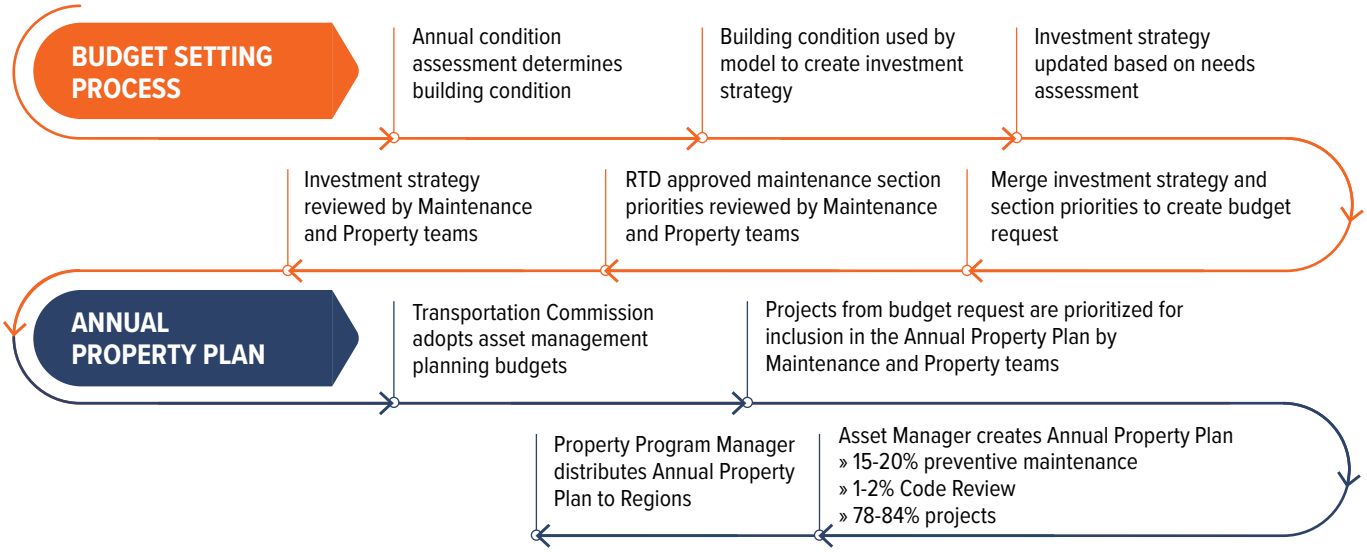
Initial Construction: consists of the development of land, including site infrastructure and construction of a new rest area on property recently purchased by CDOT or an existing CDOT-owned property that did not have a rest area on it before. Initial construction is funded by programs outside of CDOT's TAM Program, which pays to maintain the existing transportation system.

Table A.7-6 *Rest Area Treatments and Typical Unit Cost*

Work Type	Example Activity	Typical Unit Cost/Square Foot
Preservation and Preventive Maintenance	Updating sinks or toilets to low-flow models or installing a new furnace.	$100
Maintenance	Includes interior and exterior painting, concrete apron repairs, new roofs, ventilation and air condition services, new flooring, new fencing, new plumbing fixtures, and other maintenance activities.	$300
Rehabilitation	Updating a sewage treatment system or a major remodel.	$700
Reconstruction (Replacement)	Tear down and replacement of existing structure due to program changes, functional obsolescence, or the complete deterioration of rest area condition.	$2,300 (Tier 1 and Tier 2) and $1,400 (Tier 3)
Initial Construction	Development of land, including site infrastructure and construction of a new rest area.	Varies

CDOT's Rest Area Property Management program is responsible for managing the rest area conditions, including the determination of which types of treatment activities are appropriate to each category of work. This is further governed by the Property Plan and Policy Directive 60.1 (Property Management Funds Allocation). Treatment selection for rest areas is driven by annual condition assessment and AIMS model runs as presented in **Figure A.7-4**.

Figure A.7-4 *Rest Area Prioritization and Project-Selection Process*



RISK MANAGEMENT

The Rest Area program manages risk across multiple levels—enterprise, programmatic, and project/asset. Section 6 of the main TAMP document provides more information about CDOT's risk management methodology and processes.

The Rest Area program maintains a register of risks to its overall program and projects. Top risks are presented in **Table A.7-7**.

Table A.7-7 *Top Rest Area Risks*

Risk Level	Threat/ Opportunity	Risk Score[1]	Risk Management Strategy
Program	Building materials availability, impacting costs, and operations.	64.7 (T)5 x (C)2.6 x (V)5	Tolerate
Program	Construction cost escalations, year-over-year.	59.1 (T)5 x (C)2.4 x (V)5	Tolerate
Program	Changing strategic direction from leadership.	55 (T)5 x (C)2.2 x (V)5	Tolerate
Project	Limited construction industry capacity.	45.9 (T)5 x (C)1.8 x (V)5	Tolerate

1 Risk Score = Threat Likelihood (T) * Total Consequence and Consideration Score (C) * Vulnerability (V)

FINANCIAL PLAN

CDOT creates planning budgets for each asset class four years in advance. This asset plan includes an extrapolated financial plan for fiscal years 2023-31, including estimates of revenue and costs for meeting performance targets. CDOT estimates steady funding for rest areas for the next 10 years. The estimates below, combined with CDOT's life-cycle management approaches, inform the investment strategies CDOT plans to leverage to achieve system-wide asset performance targets while minimizing life-cycle costs.

FUNDING SOURCES

Starting in FY 2023, the Rest Area program receives a portion of the funds for CDOT's TAM Program to fund rehabilitation and reconstruction work types described in the rest areas Life-Cycle Planning section. Rest areas have only recently been included as part of the TAM Program.

CDOT's Maintenance Levels of Service program funds routine rest area maintenance and operations. Those activities are part of the Maintenance Levels of Service asset plan and its financial plan.

PLANNED FUNDING

Table A.7-8 summarizes the projected funding levels for rest areas for the next 10 years.

Table A.7-8 *Financial Plan for Rest Areas (in Millions)*

FY22	FY23	FY24	FY25	FY26	FY27	FY28	FY29	FY30	FY31
Not eligible	$6.9	$5.4	$4.0	$4.0	$4.0	$4.0	$4.0	$4.0	$4.0

INVESTMENT STRATEGIES

CDOT forms investment strategies based on its financial plan and life-cycle management strategies identified to achieve performance targets while minimizing life-cycle costs. The investment strategies delineate different types of work to be performed across CDOT's rest area assets over a 10-year period.

BACKGROUND: HOW INVESTMENT STRATEGIES ARE DETERMINED

Each year the current rest area inventory and condition data are loaded into the AIMS model, and the model forecasts rest area conditions over the following 20-year period. AIMS then generates a list of alternative strategies for each rest area, composed of repair, rehabilitation, and replacement treatments. These strategies are based on business rules created by CDOT in rest area treatment decision trees. The model generates a set of strategies that maximize the benefit for any given budget.

PLANNED INVESTMENTS

MAINTENANCE AND REPAIR

CDOT's maintenance crews conduct routine rest area maintenance and operations. These activities are part of the Maintenance Levels of Service asset plan and its financial plan and investment strategy. Basic repairs are funded out of the controlled and deferred maintenance budget.

REHABILITATION, RECONSTRUCTION, AND REPLACEMENT

CDOT's Rest Area Property Management program performs routine inspections, and repairs that require engineering, rehabilitation, reconstruction, and replacement of rest areas. These activities are part of the program and its financial plan and investment strategy.

PERFORMANCE GAP ANALYSIS

CDOT uses its AIMS model to forecast the performance of its rest area assets and any anticipated performance gaps annually. The results of the analysis inform the financial plan and investment strategies. Based on the most recent analysis, current funding will not allow CDOT to achieve its performance target for rest areas within the next 10 years. CDOT's ability to close performance gaps largely depends on receiving additional funding.

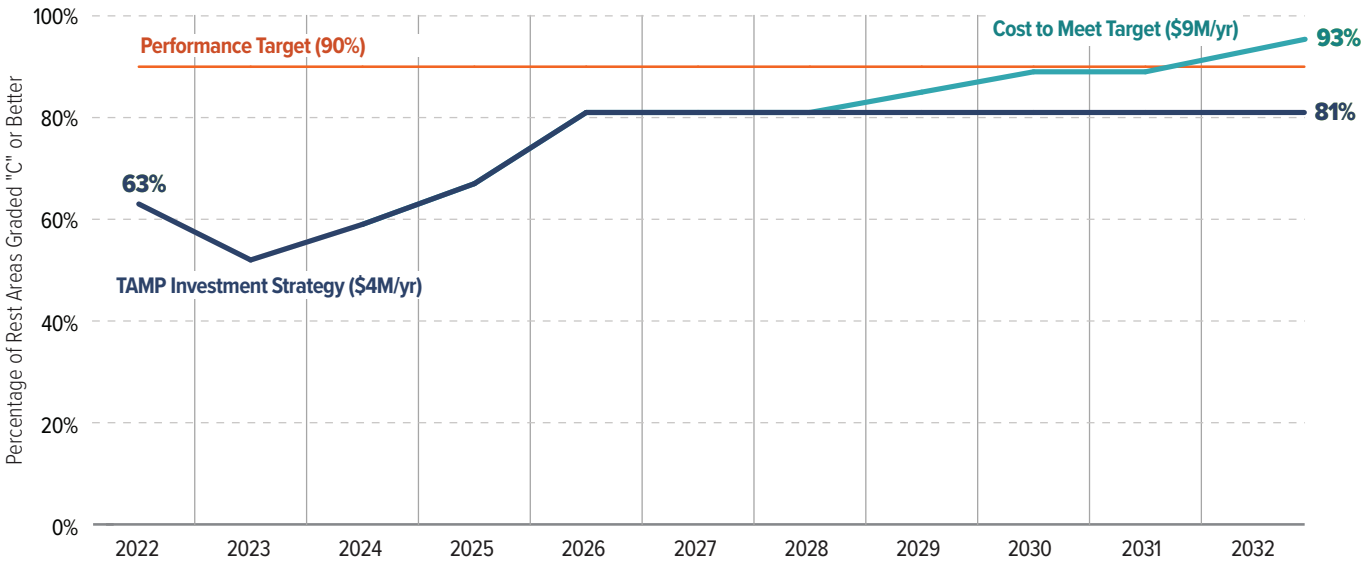
NEEDS AND PROJECTED CONDITION

CDOT's AIMS model predicts the long-term performance of rest area assets, constrained by the expected funding. The rest area ratings are deteriorated using deterioration models updated in 2022. These models are reviewed by the Property Management Team on a regular basis. Treatment costs used in the model are calculated using square-foot costs based on a rest area's total area.

As previously mentioned, expected funding ($4 million per year) is not sufficient to meet the PD 14.0 performance target, as presented in **Figure A.7-5**. An additional annual investment of at least $5 million is required to achieve the target by 2032.

Figure A.7-5 *Forecast of Rest Area Assets Performance*

The anticipated annual budget of $4 million will not meet the performance target of ensuring that 90 percent of rest areas have a C grade or better. The annual cost of meeting the target by 2032 is about $9 million, or an additional $5 million per year.



IMPACTS OF INSUFFICIENT FUNDING

Rest areas are crucial to the resiliency of CDOT's highway system. Well-managed rest areas provide a safe area for travelers to take a break from driving and to use needed facilities. These services and amenities reduce the likelihood of traffic collisions by helping to reduce driver fatigue and improve driver attention. The information provided at rest areas supports the effective use of CDOT's highway system. Rest areas also provide a location for disabled vehicles to safely wait for emergency assistance. These benefits support efficient travel and minimize delays on the highway system. Risks from insufficient funding for rest areas include impacts on roadway safety, health, public perception, and economic activities, as summarized below.

- **Safety:** Attractive, strategically placed rest areas help drivers recover from fatigue by providing a safe place to stop and rest, have a snack, or use bathroom facilities before continuing their trips. Rest areas also mitigate distracted driving by providing motorists with a safe place to talk or text on their cell phone. Maintaining functioning and sanitary rest areas minimizes health risks for travelers.
- **Public Perception:** Rest areas are often a first impression of how CDOT serves the people of Colorado. Rest areas serve as information centers for travelers to Colorado, both at entrances to the state and near resort areas. Rest areas provide information regarding trip planning, places to stay, special events, etc. As a result, they support the development of public trust in CDOT's infrastructure system and operations.
- **Financial:** Well-maintained rest areas promote tourism and economic activity, and contribute to state revenues.

OPPORTUNITIES TO CLOSE THE GAP

CDOT regularly evaluates various investment strategies and funding levels, including a review of analyses from CDOT's AIMS model to determine the best strategy to meet condition targets. CDOT may alter its existing strategy by adjusting treatments, condition targets, and other factors to help close performance gaps. CDOT also analyzes funding relative to targets at its annual budget-setting workshop for asset management and may adjust funding recommendations should analysis warrant it. Additionally, the Transportation Commission each year is briefed on performance versus targets in PD 14.0 and may adjust funding to address gaps. The Life-Cycle Planning and Investment Strategies sections of this plan describe high-level CDOT investment strategies and methods for closing performance gaps for rest areas.

STRATEGIC USE OF ADDITIONAL REVENUE

Should CDOT receive additional revenue to fund the Rest Areas asset class, the Department's first priority is to eliminate any funding gaps related to achieving the PD 14.0 performance target. Once goals are achieved, the Department will reduce Poor backlog with a priority towards the most critical and/or vulnerable assets to improve system resilience. CDOT estimates the current "Poor" backlog for Rest Areas could be eliminated with about $30 million.

FUTURE IMPROVEMENTS

Planned improvements to the Rest Areas program focus on people, processes and technology.

PEOPLE

CDOT has recently established a Rest Area Steering Committee, a collaboration between various CDOT departments, to continue developing rest area policy, planning, and more.

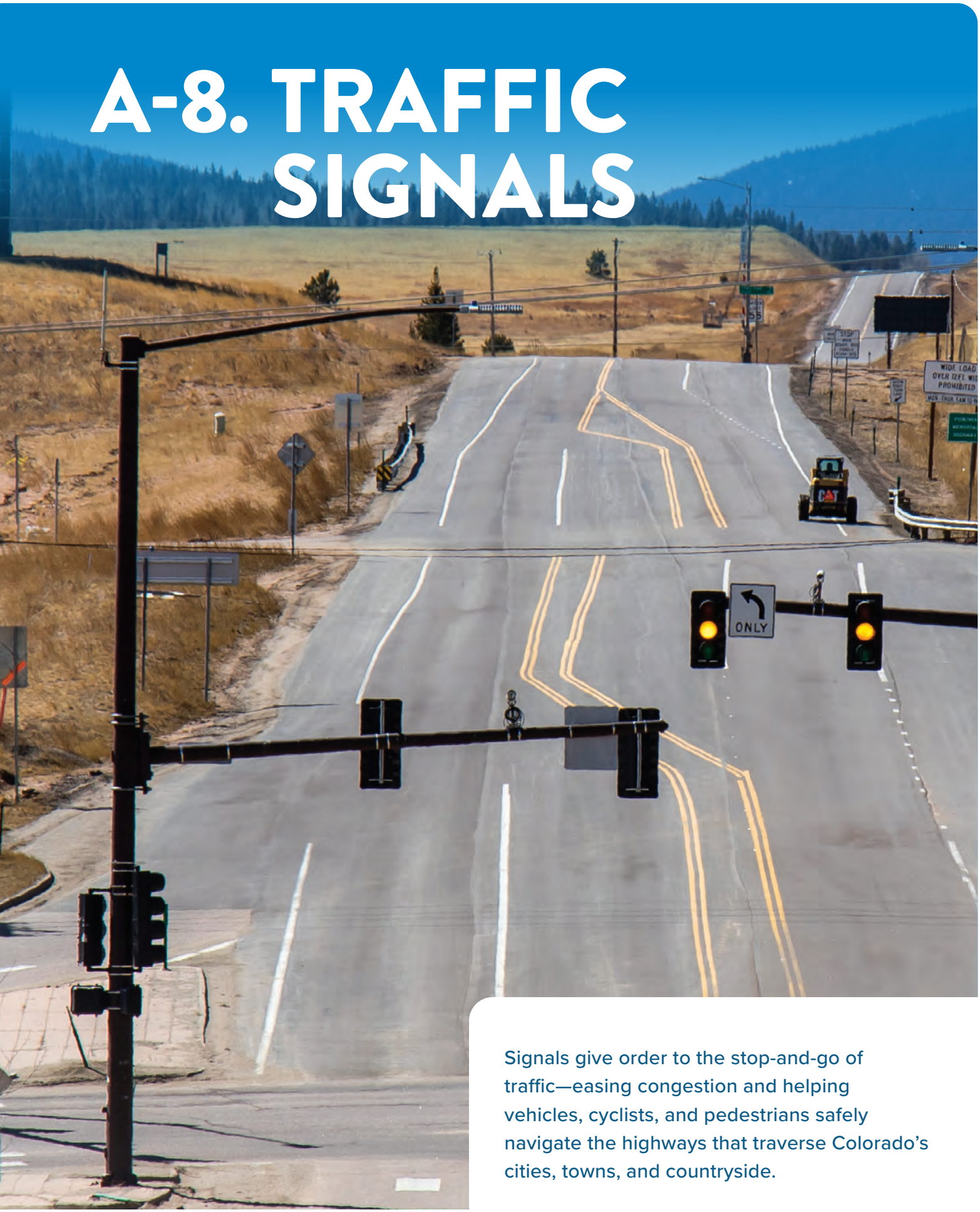
PROCESS

The Rest Areas program continues to train staff to ensure proper use of a mobile application used to assess rest areas. The resulting data is essential to complying with Colorado's 2018 Community Living Report, which requires CDOT's transportation system to meet the needs of all Coloradans. Rest Areas also are required to certify compliance with the Americans with Disabilities Act (ADA) annually. Therefore, collected data must be accurate and timely to allow the Department to fix deficiencies prior to certification.

TECHNOLOGY AND ANALYSIS

Rest Areas were added as an asset in 2018, so rest-area assessment data, such as condition scoring, remain in their infancy. Continual improvements to data collection and analysis will be needed to improve the AIMS model's forecasting capabilities for this asset class.

A-8. TRAFFIC SIGNALS



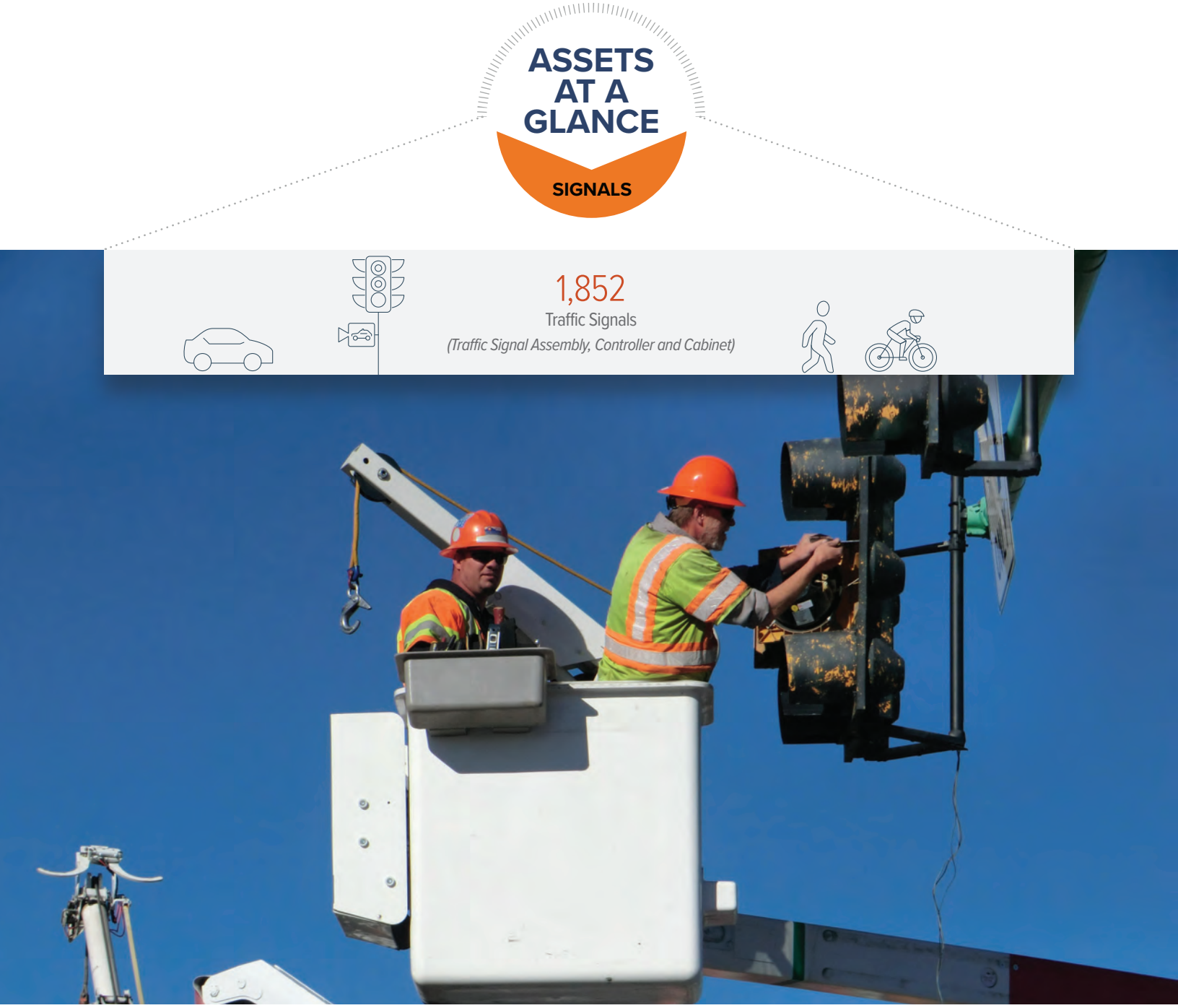
Signals give order to the stop-and-go of traffic—easing congestion and helping vehicles, cyclists, and pedestrians safely navigate the highways that traverse Colorado's cities, towns, and countryside.

CDOT owns 1,852 traffic signals, nearly half of which are managed by local agencies. As the asset owner, CDOT maintains inventory and condition data on all of its traffic signals assets and uses that data to prioritize repairs and replacements. This prioritized approach allows CDOT to minimize signal down time and manage life-cycle costs, which include replacing signals assets at the end of their useful life spans.

More than 85 percent of the signals are in Good to Fair condition. However, 7 percent of signals are in Severe condition, short of the Department's target of 2 percent. CDOT is considering a range of activities to address performance gaps, including rehabilitating signals to postpone needed replacements, upgrading technology, performing targeted maintenance and repairs to extend asset life, and replacing signalized intersections with innovative solutions.

Traffic signals are managed under a comprehensive asset-management process closely aligned with the process illustrated in the Introduction to the Asset Plans Appendix.

Figure A.8-1 *Traffic Signals Assets at a Glance*



PERFORMANCE MANAGEMENT

CDOT monitors and manages performance through routine assessments of its traffic signals and their primary components. The Department has established performance targets and measures for signals, focusing its budget and prioritizing work to achieve strategic goals and provide vital transportation services to the public.

POLICY DIRECTIVE 14.0 PERFORMANCE MEASURE

The primary performance measure for traffic signals is the percentage of signals in Severe condition. This target reflects Policy Directive 14.0 (PD 14.0) goal areas related to asset management, safety, and mobility. It represents the desired level of performance to be achieved given expected future funding.

Table A.8-1 presents the PD 14.0 target for traffic signals—that less than 2 percent of signal infrastructure should be in Severe condition. The current (2021) performance is 7 percent, or 5 percentage points from the target.

OTHER PERFORMANCE MEASURES

In addition to the percentage of traffic signals in Severe condition, CDOT considers technological or functional obsolescence to qualify signal components for replacements. This measure is primarily used in the prioritization of asset management and repair/ replacement decisions.

Table A.8-1 *CDOT Asset Management Metric and Performance Target for Signals*

SIGNALS

Measure	Target	2021 Performance
Percentage of traffic signals infrastructure in Severe condition	<2%	7%

INVENTORY AND CONDITION

CDOT's inventory of traffic signals and their condition is maintained within the Statewide Signal Asset (SSA) database and CDOT's SAP financial system. The statewide asset inventory is maintained in the SSA database, overseen by the Signal Asset Manager, in coordination with CDOT Region staff. The asset inventory is updated quarterly by Region staff and is reviewed annually by CDOT Headquarters for quality control.

INVENTORY

CDOT owns 1,852 traffic signals statewide. About 51 percent of these are managed by CDOT, and the remaining 49 percent are managed by local agencies under the Senate Bill 8 (SB 8) signal maintenance agreements. CDOT is responsible for the replacement of traffic signals it owns at the end of their useful life span, regardless of the managing agency. On average, about eight to 10 new traffic signals are constructed statewide annually. CDOT expects an annual growth in traffic signals inventory of about 0.5 to 1 percent in the future.

ASSET HIERARCHY

For asset management purposes, the inventory database for traffic signals consists of three primary components: traffic signal assembly, cabinets, and controllers. **Figure A.8-2** illustrates the elements of a traffic-signal system. Traffic signals are designed specifically for each location, so the type and number of specific elements vary for each signal.

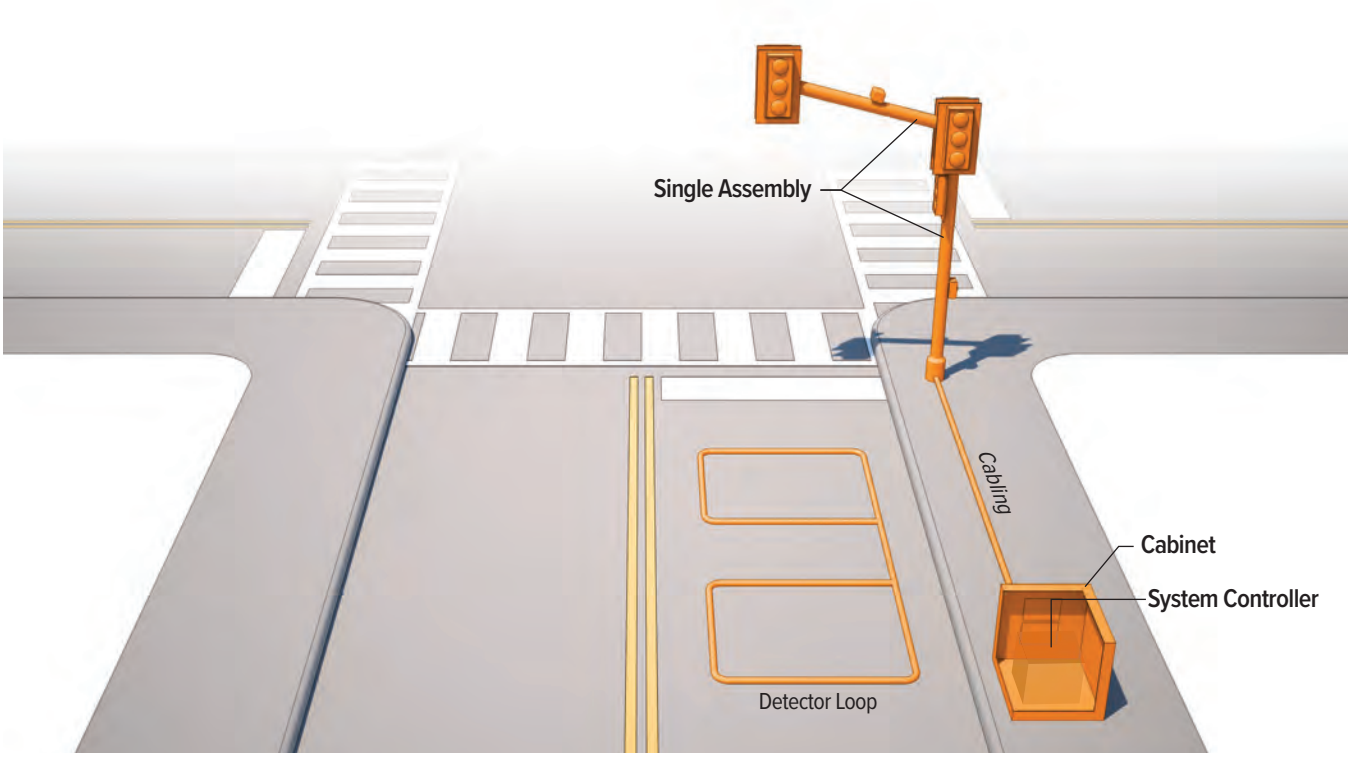
Traffic-signal assembly: The signal assembly comprises the underground and above-ground signal infrastructure at a traffic-signal intersection, including poles and mast arms, span wires, communication devices, electrical equipment, pedestrian poles and push buttons, advance warning signs, flashing beacons, signal heads, bicycle/pedestrian indications, and detection devices.

Controllers: A system controller, located within a cabinet along the roadway, manages the traffic-signal functions locally. Controllers can be networked together to manage the functions of multiple intersections. Controllers use inputs from vehicle detectors and pedestrian call boxes to monitor the operation of each intersection, coordinate signal timing between intersections, and detect errors in operation.

Cabinets: Cabinets are located at every traffic-signal intersection. The cabinet houses items such as the intersection controller, underground wiring and pull boxes, Uninterrupted Power Supply (UPS) equipment, back panel, electrical and electronic equipment, load switches, Internet Protocol (IP) devices, conflict monitor, circuit breakers, and power filters.

Figure A.8-2 *Traffic Signal Elements*

Traffic signals consist of three primary components—the traffic signal assembly, controllers, and cabinets. The cabling transfers data from the system controller to the signal assembly, and the detector loop detects vehicles passing or arriving at a certain point (e.g., approaching a traffic light).

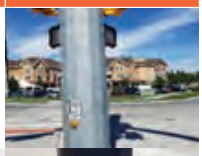
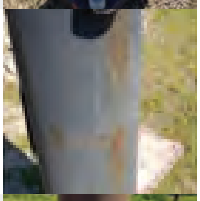


CONDITION

CDOT begins rating the condition of a traffic-signal system at the component level, and then calculates a rating for the system using a four-level scale: Good, Fair, Poor, and Severe. The condition-rating system was established by the Statewide Traffic Signal Program in coordination with Region signal maintenance and operations staff. Several data sources are used to establish condition ratings, including signal maintenance records, structural-integrity data from signal pole and mast-arm inspections conducted by the Staff Bridge Branch, highway video logs collected by the Division of Maintenance and Operations (DMO), signal-age data, and Region signal staff input.

Of these factors, the structural integrity information is given higher priority, followed by the Region maintenance staff input, and highway video logs. Information from these sources is weighted qualitatively to assign a condition rating to an asset. **Table A.8-2** summarizes the condition-rating approach used by CDOT to assess the performance of traffic signals based on asset age and condition.

Table A.8-2 *Condition Ratings for Traffic Signals*

Status	Assessment	Structure Age	Cabinet Age	Controller Age	Illustration of Asset Condition
Good	The signal is in new or near-new condition. No damage or operational problems reported. No major repairs identified during annual Maintenance Levels of Service (MLOS) survey or routine maintenance visits.	0-5 years	0-5 years	0-3 years	
Fair	The hardware infrastructure needs periodic preventive maintenance or repairs to keep the signal in operational status.	6-30 years	6-10 years	4-7 years	
Poor	The hardware infrastructure is near the end of its useful design life. Operational failures have increased due to wiring, aging, and support hardware problems. Preventive maintenance cannot reasonably extend asset life much longer. Functional or technological obsolescence is evident. Frequent maintenance visits to repair or replace aged or damaged components.	31-45 years	11-20 years	8-15 years	
Severe	Structural or technological obsolescence. Structural integrity issues identified by Staff Bridge structural inspections or by signal maintenance staff. Signal supported by span wire. For cabinets and controllers, the hardware infrastructure has reached or exceeded its intended design life and needs replacement.	>45 years	>20 years	>15 years	

CURRENT CONDITION

Table A.8-3 summarizes conditions of traffic signals, overall and by component. Eighty-four percent of signals are in Good to Fair condition, based on overall condition.

Table A.8-3 *Traffic Signal Condition, Overall and by Component - Dollar Weighted*

Asset Subcategory	Asset Condition			
	Good	*Fair*	*Poor*	*Severe*
Signal Assembly	36%	48%	9%	7%
Cabinets	73%	6%	7%	14%
Controllers	79%	3%	4%	14%
Overall Condition	36%	48%	9%	7%

CONDITION TRENDS

Table A.8-4 shows condition data for traffic signals from 2017-21. Conditions have improved by one percentage point over this period.

Table A.8-4 *Traffic Signal Condition Trends*

Measure	Target	2017	2018	2019	2020	2021
Percent of Signal Infrastructure in Severe Condition	2% or less	8%	7%	7%	7%	7%

ASSET VALUE

CDOT undertook an assessment of the asset value of signals in early 2022. The current replacement value, determined by current acquisition value, is $1.3 billion. To calculate current asset value, the replacement value is discounted by the useful life of the assets, which is based on the average age of all signal assets, plus two standard deviations of age. The current value of CDOT's traffic signals is $722 million.

LIFE-CYCLE PLANNING

Traffic-signal components are designed to provide a service life of 30 years or more. CDOT leverages analysis of condition data to prioritize repairs and preventive maintenance activities that maximize service life and replacements. The combination of these strategies allows CDOT to cost effectively manage signal downtime and life-cycle costs.

LIFE-CYCLE PLANNING

CDOT uses a condition-based approach to the life-cycle management of traffic-signals assets. However, as noted by the condition ratings defined in **Table A.8-2**, condition is in part defined by assumptions about asset age relative to expected useful life. Regular inspections, in coordination with preventive and corrective maintenance, ensure continued functionality and help extend useful life to assure maximum return-on-investment from traffic-signals assets. CDOT attempts to use signal equipment until its expected end of life or when it is deemed a risk of assembly failure—as determined by various means and reflected in its condition rating—whereupon it is replaced.

CDOT is prioritizing replacement of all existing traffic-signals assets in Severe condition, followed by assets in Poor condition. In lieu of replacing an entire assembly, viable parts may be salvaged from retired assets and reused to keep other signal systems operational. With this approach, CDOT is looking to mitigate the risk that Severe and Poor signals pose to mobility and traffic safety.

PROGRAM DECISION-MAKING

TREATMENT SELECTION

CDOT employs a variety of treatments to address signal conditions. Treatment decisions are made by CDOT Headquarters, in coordination with Region staff. CDOT uses its Asset Investment Management System (AIMS) model to determine budget needs and priorities for replacement. Currently, the traffic-signal asset management budget only funds replacement of assets in Severe condition. CDOT is considering adding rehabilitation as a treatment type.

Non-replacement work types are undertaken through the Maintenance Levels of Service program. The treatments are linked to the Federal Highway Administration (FHWA) work types in **Table A.8-5** below, along with typical unit costs.

Table A.8-5 *Traffic Signal Treatments and Unit Costs*

Work Type	Treatments	Typical Unit Cost
Preservation	Preventive maintenance activities, including cleaning/vacuuming signal cabinets; wiping camera lenses; repairing detector damages; cleaning pull boxes; painting the poles/mast arms with anti-corrosive coating; etc.	<$5,000
Maintenance	Functional (e.g., optimizing signal-timing plans), hardware (e.g., replacing malfunctioning equipment), and software treatments (e.g., software modifications/upgrades to provide additional features).	<$5,000
Rehabilitation	Rebuilding parts, such as a pole or mast arm with section loss.	$10,000 - $25,000
Reconstruction (Replacement)	Replacing an asset in Severe condition due to structural and/or functional/ technological obsolescence.	Signal Assembly/ Intersection: $650,000 Cabinets: $15,000 Controllers: $30,000
New Construction	A signal is constructed where warranted per the Manual on Uniform Traffic Control Devices (MUTCD) guidelines.	$700,000 to $750,000

Preservation (Preventive and Routine Maintenance)

Preventive and routine maintenance is performed with the purpose of reducing the frequency and severity of signal malfunctions, thereby extending the life of signal infrastructure, reducing life-cycle costs, and optimizing signal operations. CDOT Region signal supervisors oversee these activities, with in-house staff and consultants conducting the work.

Annual preventive maintenance checks are performed on every signal. During these visits, asset needs are identified and prioritized based on severity and available resources. Maintenance supervisors also review and prioritize citizen complaints from a safety and operations perspective to identify needed maintenance. The preventive and routine maintenance treatments are funded using the Maintenance Levels of Service (MLOS) budget.

Maintenance

Maintenance activities include repairing signal hardware that is located inside the cabinets, controllers, and wiring (both underground and overhead), including damage from rodent activity. In-house technicians and consultants identify needed repairs during preventive- and routine-maintenance visits. Repairs are prioritized by the Region signal supervisor based on available resources.

Functional maintenance activities focus on improvement rather than repair—including updating traffic-signal system databases and optimizing signal timing plans.

Hardware maintenance can include remedial, preventive, or modification-related activities:

- Remedial hardware maintenance includes the immediate replacement of malfunctioning or failed equipment.
- Preventive hardware maintenance involves checking equipment at scheduled intervals to minimize probability of failure.
- Hardware modification relates to addressing design flaws or other changes needed to improve equipment.
- Software maintenance includes debugging problems identified following system acceptance, or modification of software to provide additional features.

Maintenance activities are funded by the MLOS budget.

Rehabilitation

Rehabilitation activities include rebuilding traffic signal parts or components to restore them to a required functional condition and to improve longevity. The work includes surface preparation and painting of traffic-signal poles, mast arms, signal heads, luminaire arms, safety-lighting housings, pedestrian-button housings, back plates, cabinets, etc. Rehabilitation activities are funded by the MLOS budget.

Reconstruction (Replacement)

Reconstruction/replacement involves the removal of existing signal components and installation of a new system. CDOT Region staff are responsible for delivering signal-replacement projects, and the projects always involve replacing the entire signal assembly. The replacement projects are funded by the TAM Program through the Traffic Signal Asset Management (SGA) funding pool. A replacement project is triggered when a signal component reaches Severe condition. **Table A.8-2** provides the average age when the signal components are expected to be replaced.

CDOT's replacement projects are built to the latest standards and specifications, such as CDOT Maintenance & Safety (M&S) Standards; guidance in the Manual on Uniform Traffic Control Devices (MUTCD); guidance in the AASHTO Roadside Design Guide; Americans with Disabilities Act (ADA) requirements; and other applicable federal and state standards and guidelines.

New Construction

CDOT conducts "warrant analyses" to determine when construction of new traffic signals is warranted. This analysis is performed by CDOT Regions. New signal construction is typically funded by the Statewide Traffic Signal Pool (SGN), which is funded at about $1.5 million annually. Because these funds are insufficient to build more than two signals annually, several intersections statewide are awaiting funding. The new assets are added to the statewide inventory, after which they are considered in asset-management analyses.

PROJECT SELECTION AND DELIVERY

The signals project-selection process begins when CDOT's Performance and Asset Management Branch uses the AIMS model to import traffic-signal data from the SSA database and to provide a recommended list of treatments. The database includes records

for key signal components, acquisition costs, installation costs, and condition assessments. The information is derived from other data sets, such as structural inspections, maintenance work-order history logged in CDOT's financial system (SAP), and visual assessments from video runs. The AIMS model allocates 80 percent of the available funding to signal assemblies, 10 percent to controllers, and the remaining 10 percent to cabinets.

The Signal Asset Manager reviews the AIMS model's output (AIMS generated treatment list) and provides this information to the Regions. Based on the AIMS output, the Regions submit a desired list of capital replacement projects back to the Signal Asset Manager, including evaluations, prioritizations, and recommendations. The Traffic Signal Asset Steering Committee and Region staff then collaborate to finalize the project list based on fiscal constraints set by the Transportation Commission. The Signal Asset Manager delivers the final project list to the Regions. Regions then implement and deliver approved eligible signals projects.

RISK MANAGEMENT

Aligned with CDOT's overall risk-management approach, the Traffic Signals program manages risk across multiple levels—agency, programmatic, and project/asset. Section 6 of the overall TAMP provides more information about CDOT's risk-management methodology and processes.

The Traffic Signals program maintains a register of risks to its overall program and projects. Top risks to the Traffic Signals program are presented in **Table A.8-6**.

Table A.8-6 *Top Traffic Signal Risks*

Risk Level	Threat/Opportunity	Risk Score[1]	Risk-Management Strategy
Program	Changing federal and state laws, policies, standards, and specifications in the near future (e.g., Update to the Manual on Uniform Traffic Control Devices [MUTCD], ADA requirements, multi-modal considerations).	39 (T)5 * (C)3.9 * (V)2	Treat, tolerate—maintain existing infrastructure, replace/upgrade to the latest standards when asset treatment is required.
Project	Loss of communication due to fiber damage or utility-line damage (e.g., loss of power, fiber cuts).	37.4 (T)5 * (C)3.7 * (V)2	Treat by location. Tolerate—repair, replace, where required. Collect damages from utility operators.
Project	Signal components (cabinets, poles) damaged by vehicles.	37.4 (T)5 * (C)3.7 * (V)2	Treat, tolerate, terminate. Repair, replace based on post-event inspection.
Program	Increased construction costs and labor/ material shortages.	36.0 (T)5 * (C)3.6 * (V)2	Treat, tolerate—maintain existing infrastructure, implement innovative project-delivery methods.

1 *Risk Score = Threat Likelihood (T) * Total Consequence and Consideration Score (C) * Vulnerability (V)*

FINANCIAL PLAN

CDOT sets planning budgets for traffic signals four years in advance. For the 10-year financial plan in this section, the Department assumes steady funding for the six years that follow these planning budgets. These funding estimates, combined with life-cycle management approaches discussed in the previous section, inform the investment strategies CDOT plans to leverage to achieve system-wide asset performance goals while minimizing life-cycle costs.

FUNDING SOURCES

The Traffic Signal program manages two funding pools:

- The Statewide Traffic Signal (SGN) pool delivers funding to each Region on an annual basis. These funds are designated specifically for new signal construction or signal system-related improvements.
- The Statewide Signal Asset Management (SGA) pool delivers funding for capital replacement to each Region on an annual basis to address traffic signal infrastructure that is in Severe condition. The SGA pool funding is divided into six parts. Region 1 receives two parts, while Regions 2-5 receive one part each.

CDOT's FASTER Safety program may be used for projects that include repair or replacement of traffic signal boxes, controllers, assemblies, and other associated signal infrastructure. Other projects that may receive the FASTER Safety funds include those replacing signal assets that are in deteriorating condition and do not meet current standards in the FHWA MUTCD, CDOT Maintenance & Safety Standards, and other regulations.

Preservation, maintenance, and rehabilitation activities are funded by the Maintenance Levels of Service (MLOS) budget.

PLANNED FUNDING

The Traffic Signal asset-management program, which focuses on asset replacement, develops a treatment list for each year of a rolling four-year period. Treatments ultimately become standalone projects or are bundled by staff into projects that may encompass multiple treatments. **Table A.8-7** shows the annual planned budget for traffic signals.

Table A.8-7 *Financial Plan for Traffic Signal Assets (in Millions)*

FY22	FY23	FY24	FY25	FY26	FY27	FY28	FY29	FY30	FY31
$12.5	$9.2	$9.2	$8.2	$8.2	$8.2	$8.2	$8.2	$8.2	$8.2

INVESTMENT STRATEGIES

CDOT forms investment strategies based on its financial plan and life-cycle management strategies identified to achieve system-wide asset performance goals while minimizing life-cycle costs. The investment strategies delineate different types of work to be performed across CDOT's traffic signals assets over a 10-year period.

BACKGROUND: DETERMINING ASSET STRATEGIES

CDOT forecasts the condition of traffic signals using its AIMS model. The analysis predicts the condition of each signal component (i.e., assembly, controller, and cabinet) for a 20-year period, using deterioration assumptions developed within the Department. The model also generates a list of treatment strategies for each signal component. CDOT uses the model to run various budget scenarios to determine performance impacts and recommended construction programs. Each component is analyzed separately, with yearly budgets established for each component type.

PLANNED INVESTMENTS

The majority of traffic-signal investments are aimed at replacing signals in Severe condition. CDOT plans to invest a total budget of $8.2 million annually, beginning in fiscal year 2025, to maintain traffic signals assets, with 5 percent of that total allocated for emergency replacements.

PERFORMANCE GAP ANALYSIS

CDOT uses a performance-driven approach to manage traffic signals. This section describes the projected performance of these assets given the planned funding and investment strategies described in the previous two sections. The section then compares projected performance against the performance target. CDOT's ability to close performance gaps largely depends on receiving additional funding. For traffic signals, CDOT also is assessing additional opportunities to close performance gaps that focus on adjustments to life-cycle planning strategies.

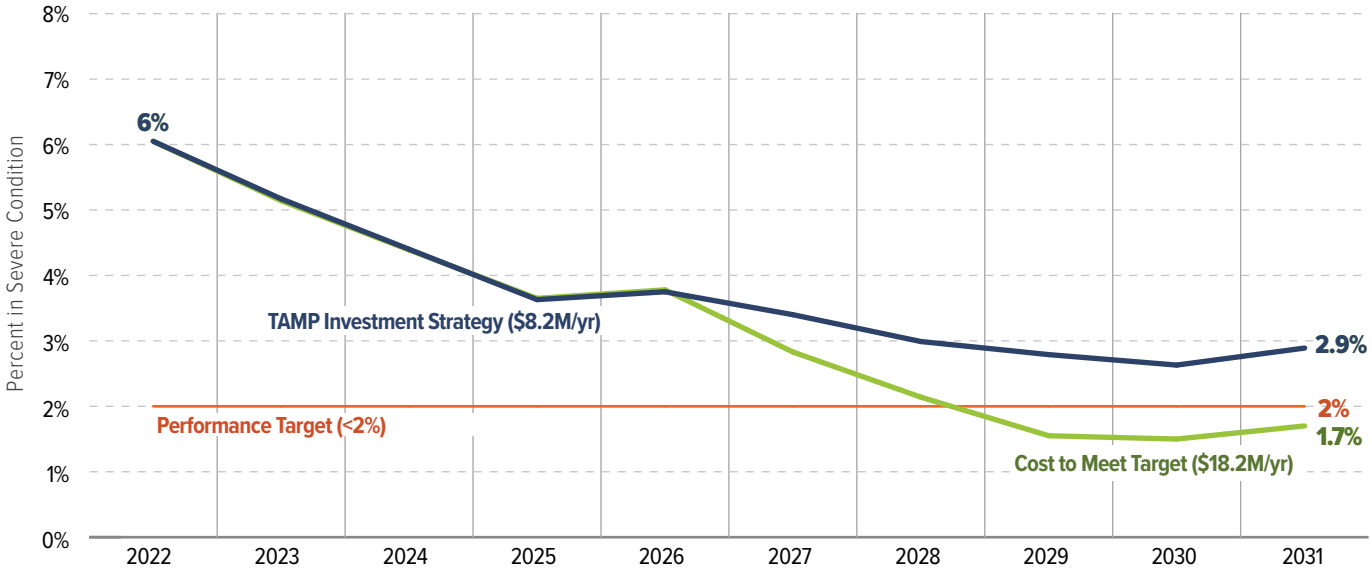
NEEDS AND PROJECTED CONDITION

CDOT's AIMS model predicts the long-term performance of signals given expected funding. Signal components deteriorate in the model using step functions based on the expected life cycle of each component (i.e., assembly, controller, and cabinet). The components deteriorate from Good to Fair, then to Poor, and then to Severe based on the expected life of each component. The model assumes that 80 percent of planned budgets is dedicated to signal assemblies, while 10 percent is dedicated to cabinets, and 10 percent to controllers.

At planned funding levels (about $8.2 million annually), traffic signals are not expected to meet the performance target of having no more than 2 percent of signals in Severe condition by 2031. As shown in **Figure A.8-3**, an additional $10 million in annual budget is required to meet CDOT's performance target by 2029 and sustain that state until year 2033. At that point in time, a significant number of signals owned by CDOT will begin reaching the end of their designed service lives. To sustain the targeted performance beyond 2033, an additional $25-$50 million in annual budget will be required to replace signals.

Figure A.8-3 *Forecasted Percentage of Signals in Severe Condition*

The anticipated annual budget of $8.2 million will not meet the performance target of ensuring that less than 2 percent of traffic signals are in severe condition. The annual cost of meeting the target by 2031 is about $18.2 million, or an additional $10 million per year.



IMPACTS OF INSUFFICIENT FUNDING

Traffic signals are crucial to the resiliency of CDOT's highway system. As a result of insufficient funding, the following risks would be increased:

- **Safety:** An increased number of signals in Severe condition could lead to increased signal downtime or structural failures, posing safety risks.
- **Effectiveness:** With more assets in Poor and Severe Condition, CDOT may need to divert funding from planned work to address emergency repairs and replacements.
- **Mobility:** More signal failures may increase travel delay, congestion, and conflicts between highway users.
- **Cybersecurity:** Technologically obsolete signal equipment could lead to cybersecurity risks.
- **Efficiency:** Signals in Poor or Severe condition could increase maintenance costs needed to achieve satisfactory asset condition.

OPPORTUNITIES TO CLOSE THE GAP

CDOT has reduced the number of traffic signal components in Severe condition in recent years. However, current funding is not expected to support achieving the performance target in the 10-year TAMP analysis period. Additionally, CDOT is expecting a significant number of traffic signals to reach the end of their design-service lives starting in 2033. To replace these systems as they reach their design lives, an estimated additional $25 to $50 million annually (over planned funding levels) is required. CDOT is exploring several strategies to close the existing performance gap:

- Currently, traffic signal assemblies are being replaced or prioritized based on issues with structural integrity. The CDOT treatment types available for those assemblies are “replacement” or “rehabilitation.” The Department is identifying the traffic-signal assemblies needing rehabilitation. The rehabilitation strategy may increase the useful life of signal assemblies, thereby pushing the needed replacement strategy into future years.
- Signal cabinets and controllers are being replaced primarily due to technological obsolescence. Each location is being reviewed from an operations perspective, and technology upgrades are being performed where necessary.
- Annual preventive maintenance activities ensure that components of traffic signal infrastructure are sufficiently serviced or tuned to prevent equipment failures, ensuring optimal operation, and extending the life of signal assets.
- Routine maintenance ensures that signal concerns are addressed in a timely manner, including for emergency responses during equipment failures, to quickly restore the normal operation of traffic signals.

To address expected funding shortfalls in the 2030s, CDOT will evaluate several strategies, including:

- Using targeted maintenance and repairs to extend the service lives of current signals, delaying the need for replacements.
- Increasing funding for traffic signals earlier than 2033 to replace some assets before the end of their service lives.
- Replacing signalized intersections with other designs, such as roundabouts, to reduce the number of signals in service.

STRATEGIC USE OF ADDITIONAL REVENUE

Should CDOT receive additional revenue to fund the Traffic Signals asset class, the Department’s first priority is to eliminate any funding gaps related to achieving the PD 14.0 performance target. Once goals are achieved, the Department will reduce the Severe backlog with a priority towards the most critical and/or vulnerable assets to improve system resilience. CDOT estimates the “Severe” backlog for Traffic Signals could be eliminated with about $185 million.

FUTURE IMPROVEMENTS

CDOT plans several improvements to processes, technology, and analysis capabilities to increase the efficiency and effectiveness of the Traffic Signals program.

PROCESS

CDOT plans to improve its management processes for traffic signals over the next 10 years, including the following activities.

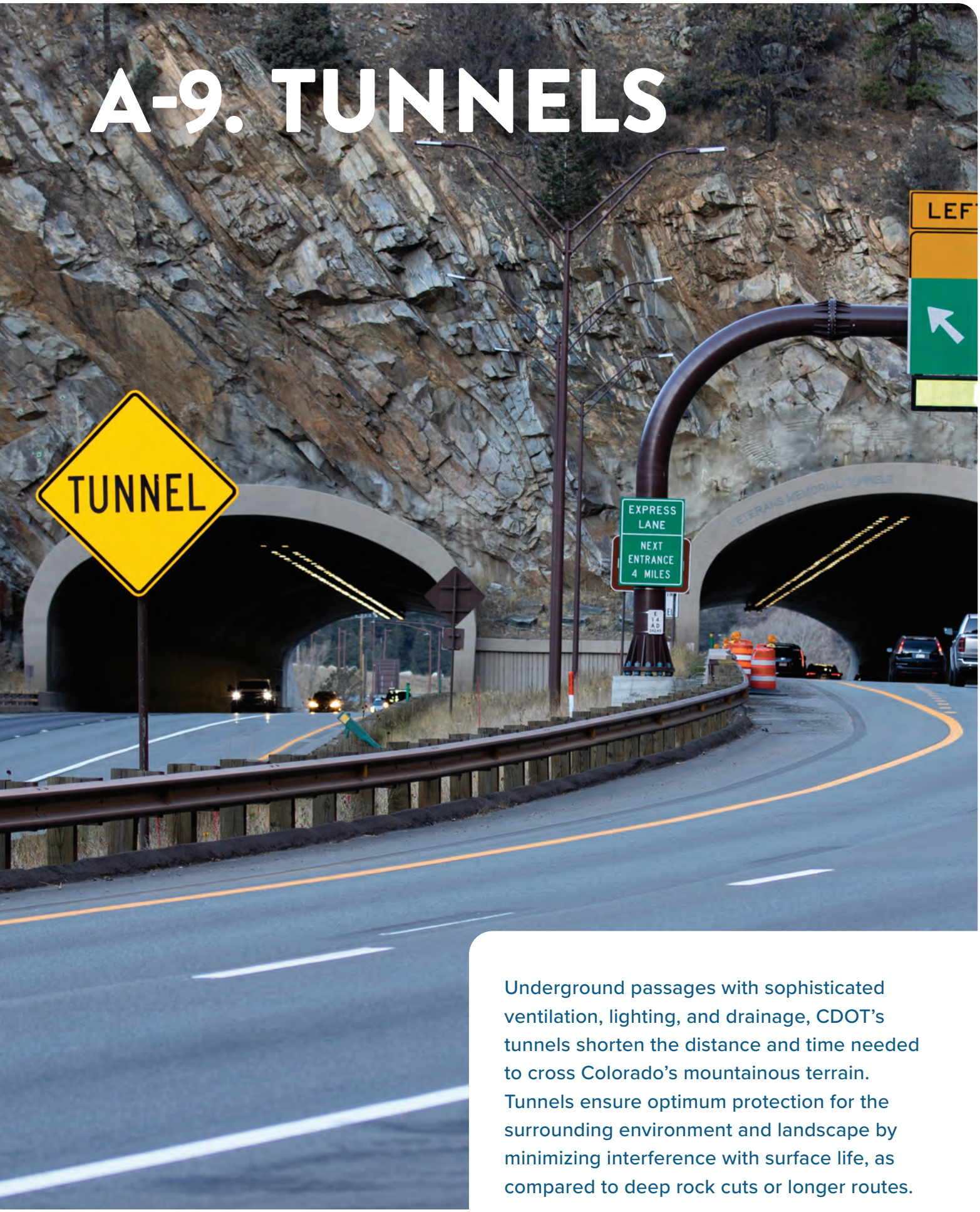
- **Identification/classification of signal maintenance activities/costs:** Maintenance activities related to traffic signals assets are currently being charged to a one-mile section in SAP, CDOT's financial system. In the future, traffic signal assets and subcomponents will be identified in SAP so that the asset-related activities can be charged to a particular location. This will provide the granular information needed to make informed decisions on maintenance and repair/replacement activities. Work Manager, a web-based tool, is being piloted in some regions to efficiently log traffic-signal work orders.
- **Automation of preventive maintenance data-collection process:** The data collection staff and technicians will be trained on the new approach, including how to log the condition data into the mobile application. This GIS-based application is being piloted in Region 1.

TECHNOLOGY AND ANALYSIS CAPABILITIES

Several planned improvements are being explored to enhance traffic-signal technology and to support the analysis process, as summarized below.

- **Review of inputs in AIMS model:** In particular, the deterioration models should be continuously reviewed and updated. They could be enhanced to be equipment-type specific. The review of the deterioration curves should reflect the actual age when the signals become inoperable or when there is a safety issue.
- **Automated Traffic-Signal Performance Measurement:** Following upgrades to the existing traffic signal infrastructure, CDOT is considering automating performance measurement by:
  - Updating old signal controllers to newer advanced transportation controllers (ATC).
  - Updating existing signal cabinets to ATC cabinets at the end of their useful life cycle.
  - Upgrading the Central Traffic Signal Control System statewide.
  - Establishing Center-to-Center Communication (C2C) between CDOT Regions and the Colorado Traffic Management Center (CTMC) to manage the signal systems after normal working hours, thereby providing 24/7 active management of the arterial corridors.
  - Implementing Automated Traffic Signal Performance Measures (ATSPMs) to proactively manage the operation and maintenance activities.
- **Traffic Adaptive Technology:** The traffic signal infrastructure (signal timing) will be adapted to be based on the traffic measurement in real time, making traffic-signal operations more accurate and reliable.
- **Future Connected-and-Automated Vehicle (CAV) Integration Capabilities:** The existing Intelight ATC signal controllers deployed in recent years have CAV integration capabilities. Additional instrumentation is required, such as on-board units (OBU), roadside units (RSU), communication devices, and field infrastructure, to deploy CAV technology on arterial corridors. A pilot project is underway in Region 1 primarily focused on a Snowplow Priority application, using CAV technology.
- **Integration and Communication with Other Devices or Software:** CDOT is considering system-level integration with the recently deployed Advance Transportation Management System (ATMS) at the Colorado Traffic Management Center. The system brings together all transportation/traffic related applications and stakeholders to make data-driven decisions possible using system-wide data and analytics.

A-9. TUNNELS



Underground passages with sophisticated ventilation, lighting, and drainage, CDOT's tunnels shorten the distance and time needed to cross Colorado's mountainous terrain. Tunnels ensure optimum protection for the surrounding environment and landscape by minimizing interference with surface life, as compared to deep rock cuts or longer routes.

CDOT tunnels are managed in alignment with the CDOT asset-management process described in the Introduction to the Asset Plan Appendix. While planned funding levels are expected to achieve a desired state of good repair for the next 10 years, as measured by CDOT's primary tunnels metric, significant modernization and other needs fall outside that metric. These needs will be met partly through new funding through the Statewide Bridge and Tunnel Enterprise, which added tunnels to its purview in 2021 (see page 23 of the main TAMP document).

Figure A.9-1 *Tunnel Assets at a Glance*

PERFORMANCE MANAGEMENT

The performance of tunnels is monitored and managed as part of CDOT's Division of Maintenance and Operations, along with the Staff Bridge Branch. In 2021, the Statewide Bridge and Tunnel Enterprise also began contributing to the management of tunnels. Performance targets inform funding decisions and track how well these assets are supporting the agency's strategic goals and the transportation services provided to the public.

POLICY DIRECTIVE 14.0 PERFORMANCE MEASURE

The asset management program for tunnels contributes to all Policy Directive 14.0 (PD 14.0) performance areas. Tunnels are integral to the performance, resilience, and reliability of CDOT's highway network. The PD 14.0 measure for maintaining tunnels in a state of good repair is the percentage of the network tunnel length with all elements in equal or better condition than 2.5 Weighted Condition Index (WCI). The process for assessing tunnel condition is described in the Inventory and Condition section. **Table A.9-1** shows the PD 14.0 target and the 2020 performance for tunnels.

CDOT considers its tunnels to be meeting the performance target if 75 percent of the network tunnel length have all elements in equal or better condition than 2.5 WCI. The current (2020) performance is 39 percent.

Table A.9-1 *CDOT Asset Management Metric and Performance Target for Tunnels*

TUNNELS

Measure	Target	2020 Performance
Percentage of the network tunnel length with all elements in equal or better condition than 2.5 WCI	75%	39%

INVENTORY AND CONDITION

The CDOT Staff Bridge Branch oversees the collection and management of CDOT's tunnel inventory and condition information. The inventory is updated with condition information according to National Tunnel Inspection Specifications (NTIS) established under 23 CFR 650.[1]

INVENTORY

As of 2020, CDOT owns and maintains 20 tunnels, with a total length of about seven miles, as documented in **Table A.9-2**. CDOT staff are continuously onsite at four of these tunnels to operate and maintain the facilities. Staffed tunnels represent about 70 percent of the total tunnel length under CDOT control.

Table A.9-2 *Inventory of Tunnels Assets (2020)*

Inventory Unit	Current Count	Length (ft.)
Staffed	4	25,906
Unstaffed	16	11,588
Total	20	37,494

Examples of Tunnel System Assets

1 eCFR :: 23 CFR Part 650 -- Bridges, Structures, and Hydraulics

ASSET HIERARCHY

CDOT's typical tunnel system consists of seven general classes of tunnel elements (see **Table A.9-3**). CDOT tracks the condition and/or functionality of major elements and other components that comprise each tunnel. **Table A.9-3** provides the element classes and examples of elements within each element class.

Table A.9-3 *Tunnel Element Classes*

Element Class	Examples of Elements
Structural	Tunnel liners, tunnel roof girders, columns/piles, cross passageways, interior walls, ceiling girders, and panels
Mechanical	Ventilation systems, tunnel drainage, emergency generator, and flood gate
Fire/Life Safety/Security	Fire detection and protection, emergency communications
Electrical	Electrical supply and distribution including emergency power
Lighting	Tunnel and emergency lighting
Civil	Wearing surface, traffic barrier, pedestrian railing, and roadway
Sign	Traffic guidance, pedestrian egress signs, variable-message boards, and lane signals

CONDITION

CDOT's condition data aligns with National Tunnel Inspection program regulations. CDOT's Staff Bridge Branch contracts with certified tunnel-inspection engineers to collect tunnel inspection data. Tunnel condition surveys and inspections are performed every 24 months and include geotechnical structure, structural elements, tunnel systems, and life-safety components. Condition assessment by professional engineers is critical for consistent and high-quality data collection. Inventory and condition data are reported to the Federal Highway Administration (FHWA) annually.

Inspection data is based on a 1-4 condition rating scale, also known as "Condition State," as summarized in **Table A.9-4**. Condition data from inspections are used within performance models. Tunnel element age also is collected to predict the remaining life for assets, and the information is used in the performance model.

Table A.9-4 *Condition-Rating Methodology for Tunnel Elements*

Condition States	Assessment	Condition Category
State 1	No notable distress	Good
State 2	Isolated breakdowns or deterioration	Fair
State 3	Widespread deterioration or breakdowns without reducing load capacity	Poor
State 4	The condition warrants a structural review to determine the effect on strength or serviceability of the element or tunnel, or a structural review has been completed and the defects impact strength and serviceability of the element or tunnel	Severe

CONDITION TRENDS

As of 2020, 39 percent of the network tunnel length was in equal or better condition than 2.5 WCI, short of the PD 14.0 target of 75 percent, as shown in **Table A.9-5**.

In the table, condition numbers vary significantly from year to year. Some variance is due to changes within the Eisenhower-Johnson Memorial Tunnels (EJMT).

These tunnels are just over 1.5 miles long, account for 47% of the tunnel network length, and therefore annual changes in their condition have a significant impact on the overall tunnel-condition metric, which is heavily influenced by length. The EJMT is almost 50 years old and its infrastructure is aging. Repairs were undertaken prior to the 2018 results and further repairs have begun in 2022.

Table A.9-5 *Condition Trends for Tunnels*

Year	Percentage of network tunnel length with all elements in equal or better condition than 2.5 Weighted Condition Index (WCI)
2015	47%
2016	45%
2017	66%
2018	91%
2019	N/A
2020	39%

ASSET VALUE

CDOT undertook an assessment of asset value in 2022 for this document. The current replacement value of tunnels is determined by using a unit cost for tunnel elements. This replacement value is $3.2 billion.

To calculate current asset value, the replacement value is adjusted by the condition rating. The current value of tunnel assets is $2.8 billion.

LIFE-CYCLE PLANNING

CDOT analyzes its tunnel inventory and inspection data to forecast investment needs and to set work priorities. This process is known as life-cycle planning and accounts for the whole-life costs of planning, constructing, and maintaining tunnels. In doing so, the process aims to minimize long-term costs while preserving or improving condition. CDOT's tunnel-investment plan leverages findings from annual inspections, as well as treatment recommendations for the next 20 years from CDOT's asset model, to identify and prioritize treatments for tunnels.

LIFE-CYCLE PLANNING

CDOT uses a condition-based approach for the life-cycle management of tunnels. Condition data and remaining life is used to determine the appropriate types and timing of work and to prioritize potential work within available budgets. As part of the tunnel-maintenance program, CDOT performs cost-benefit analysis to determine treatment program priorities. Since tunnels are underground, their performance is significantly influenced by local geologic conditions. Unfavorable conditions, such as soft soils or rock with weak planes intersecting a tunnel, can impact tunnel design, construction, and long-term performance.

CDOT's Asset Investment Management System (AIMS) model supports life-cycle planning analysis. It begins by utilizing deterioration models to forecast the future condition for each tunnel element. The model then generates a list of possible treatment strategies for each tunnel element, consisting of rehabilitation and replacement treatments, for each analysis year. During the generation of strategies, the model's analysis does not consider the budget. The analysis begins to consider the budget once all alternative strategies have been generated and optimization begins. The model's optimization process then selects a set of treatments, within a given budget constraint, that maximizes the benefit to the network.

In addition to the AIMS model described above, CDOT performs a risk-based prioritization using a Multi-Objective Decision Analysis (MODA) tool. This MODA tool is a secondary filter on the AIMS recommendations. This analysis assigns an effectiveness score to each treatment recommendation based on three measures:

- Level of service: preservation, mobility, safety, economic vitality, security, and environment.
- Cost-effectiveness: capital cost, remaining life, and annual cost-per-daily-vehicle.
- Risk-based urgency: remaining life, condition, regulatory, compliance, and risk of unplanned events.

Each tunnel treatment is scored based on the three measures and rolled up to a total score. Priority is assigned to tunnels with the highest total scores. This then forms the Tunnel Prioritization list.

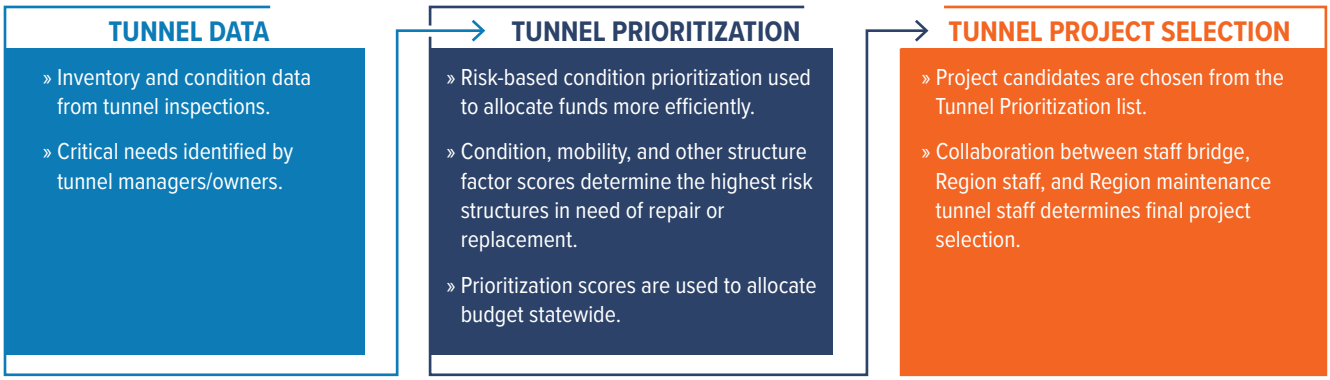
PROGRAM DECISION-MAKING

The project-selection process for tunnels is a collaborative process between the Tunnel Asset Manager, Office of Financial Management and Budget (OFMB), Region Business Office, Region Tunnel Maintenance, Regional Transportation Director, and the Region Program Engineer, among others. An overview of the process is shown in **Figure A.9-2**.

The Tunnel Asset Manager uses the AIMS model and tunnel-prioritization process described above to generate a candidate list of tunnel treatments. The candidate list is then shared with Region tunnel maintenance staff, the Resident Engineer, and the Region Program Engineer for consideration. Using

their feedback, the Tunnel Asset Manager then provides a final list to the Regional Transportation Director, assigning budgets and creating projects from the treatments. The Regional Transportation Director is responsible for project delivery and tunnel operations. Due to limited funding, project candidates are primarily chosen from the Tunnel Prioritization list.

Figure A.9-2 *Tunnel Project Prioritization and Selection Process*



TREATMENT SELECTION

Treatments are used to correct the condition of an asset or to prolong its life. Treatments are the outcome of the life-cycle planning process. **Table A.9-6** identifies the type of treatment activities by FHWA work type.

Table A.9-6 *Tunnels Life-Cycle Management Activities Undertaken*

Work Type	Tunnel Treatment/Activity	Typical Unit Cost/ Square Foot
Preservation	Varies	$100
Maintenance	Maintenance activities performed by MLOS or maintenance-services contracts	$50
Rehabilitation	Removing and replacing parts of systems	$250
Reconstruction (Replacement)	Major system replacements or upgrades	$500
Initial Construction	Construction of a new tunnel or adding lanes to an existing tunnel	$670

RISK MANAGEMENT

The Tunnels program manages risk across multiple levels—agency, programmatic, and project/asset. Section 6 of the main TAMP document provides more information about CDOT's risk-management processes.

The Tunnels program maintains a register of risks to its overall program and projects. Top risks are presented in **Table A.9-7**.

Table A.9-7 *Top Tunnels Risks*

Risk Level	Threat/ Opportunity	Risk Score[2]	Risk-Management Strategy
Project	System failure	116 (T)5 x (C)5.8 x (V)4	Inspections, maintenance plan
Project	Tunnel blockage/closure	110 (T)5 x (C)5.5 x (V)4	Scaling, incident management plan, CCTV, personnel, anti-icing

2 Risk Score = Threat Likelihood (T) * Total Consequence and Consideration Score (C) * Vulnerability (V)

FINANCIAL PLAN

CDOT creates planning budgets for tunnels and other asset-management programs four years in advance. For this financial plan, CDOT has carried forward fiscal year 2025 budget levels for fiscal years 2026-31. These estimates, combined with CDOT's life-cycle management approaches, inform the investment strategies intended to achieve system-wide asset performance goals while minimizing costs.

FUNDING SOURCES

The Tunnels program receives a portion of the funds for CDOT's overall TAM Program to fund rehabilitation and reconstruction work types described in the Life-Cycle Planning section.

Separately, CDOT's Maintenance Levels of Service (MLOS) program funds some maintenance activities for tunnels that do not require engineering. Those activities are part of the MLOS Asset Plan and its financial plan.

Bridge and Tunnel Enterprise funding has been included in the bridge financial plan and has not been included here. BTE is expected to become a significant source of tunnels revenue going forward.

PLANNED FUNDING

Table A.9-8 summarizes projected funding levels for the Tunnels program for fiscal years 2022-31.

Table A.9-8 *Financial Plan for Tunnels (in Millions)*

FY22	FY23	FY24	FY25	FY26	FY27	FY28	FY29	FY30	FY31
$9.4	$9.8	$9.8	$9.8	$9.8	$9.8	$9.8	$9.8	$9.8	$9.8

PERFORMANCE GAP ANALYSIS

CDOT uses its AIMS model to forecast the performance of tunnels and to identify potential performance gaps. The results of this analysis inform the financial plan and investment strategies. Based on the most recent analysis, current funding will allow CDOT to achieve its primary performance target for tunnels. The Department's ability to avoid performance gaps depends on receiving continuous funding.

NEEDS AND PROJECTED CONDITION

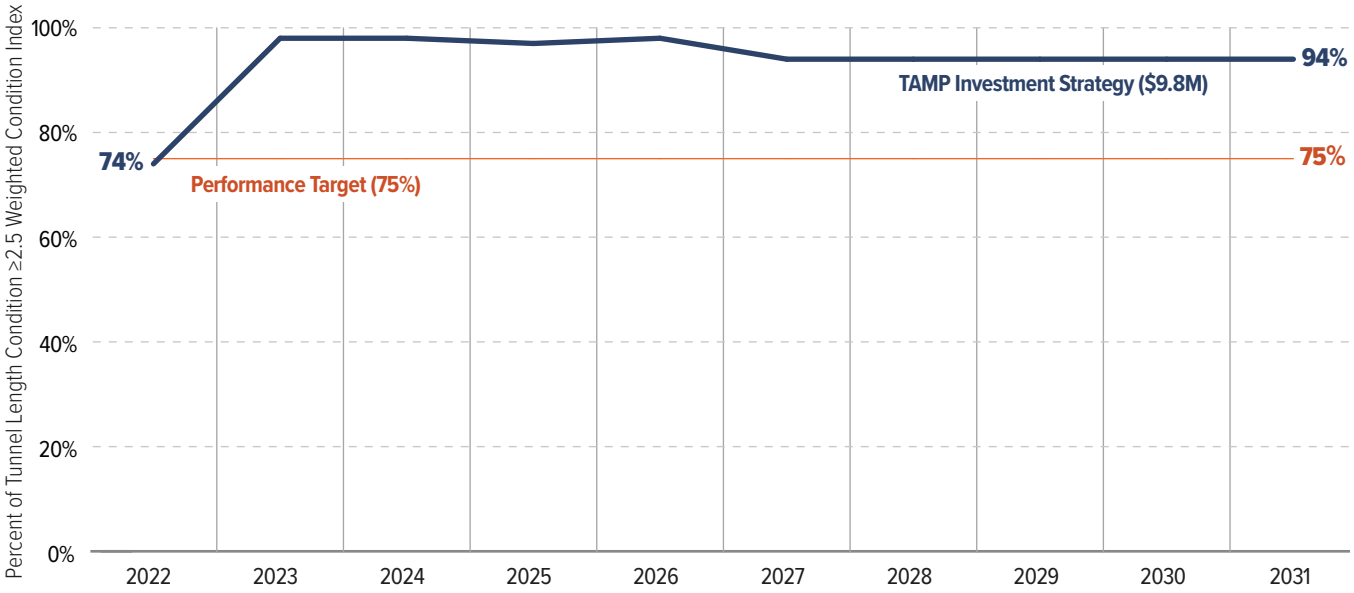
CDOT's AIMS model forecasts the long-term performance of tunnels given expected funding. Tunnel ratings are deteriorated using deterioration models developed in 2016. These models use "transition-probability matrices" (TPMs) for each tunnel element to identify when it transitions to the next condition state. Each year, once the quantity of elements in condition states 1-4 are known for a tunnel, the Weighted Condition Index for the tunnel element is recalculated.

CDOT's planned budget levels for tunnels ($9.8 million per year) are expected to be sufficient funding to meet the Policy Directive 14.0 performance target until 2031, as shown in **Figure A.9-3**. However, certain modernization and other needs are not reflected in this primary metric, which focuses on asset condition.

The 2022 condition shown in **Figure A.9-3** differs greatly from the current (2020) condition because of the forecasted impact of planned improvements.

Figure A.9-3 *Forecast of Tunnel Assets Performance*

The anticipated annual budget of $9.8 million will meet the performance target of ensuring that 75 percent of tunnel length has a weighted condition index ≥2.5.



IMPACTS OF INSUFFICIENT FUNDING

Tunnels are crucial to the mobility, safety, and resilience of CDOT's highway system. As a result of insufficient funding, the following outcomes may be affected:

- **Safety:** Traveling through mountainous terrain can be a high-risk activity because of narrow roads and sharp turns. Tunnels mitigate these high-risk situations, reducing the frequency and severity of collisions and run-off-the-road accidents.
- **Economic:** Tunnels reduce travel time. If tunnels are not in service, highway users must take detours through mountainous terrain.
- **Environmental:** Tunnels reduce the need for open cuts or longer cut-fill sections. They preserve the landscape and minimize damage to wildlife habitats.
- **Public-Perception:** Through improved safety, improved user experience, and economic benefits, tunnels improve public trust in CDOT's infrastructure.

OPPORTUNITIES TO CLOSE THE GAP

CDOT regularly evaluates tunnels investment strategies and funding levels, including a review of analyses from its AIMS model to determine the best strategy to meet condition targets. CDOT may alter its existing strategy by adjusting treatments, condition targets, and other factors to help close performance gaps. CDOT also analyzes funding relative to targets at its annual budget-setting workshop for asset management. Additionally, the Transportation Commission each year is briefed on performance versus Policy Directive 14.0 targets and may adjust funding to address gaps. The Life-Cycle Planning and Investment Strategies sections of this asset plan describe high-level CDOT investment strategies and methods for closing performance gaps for tunnels. Based upon the investment strategies in this asset plan, CDOT projects no performance gap for the *primary* tunnels metric over the next 10 years.

STRATEGIC USE OF ADDITIONAL REVENUE

Should CDOT receive additional revenue to fund the Tunnels asset class, the Department's first priority is to eliminate any funding gaps related to achieving the PD 14.0 performance target. Once goals are achieved, the Department will reduce Poor backlog with a priority towards the most critical and/or vulnerable assets to improve system resilience. CDOT estimates the current "Poor" backlog for Tunnels could be eliminated with about $150 million.

FUTURE IMPROVEMENTS

Intended asset management improvements to the Tunnels program address processes and technology.

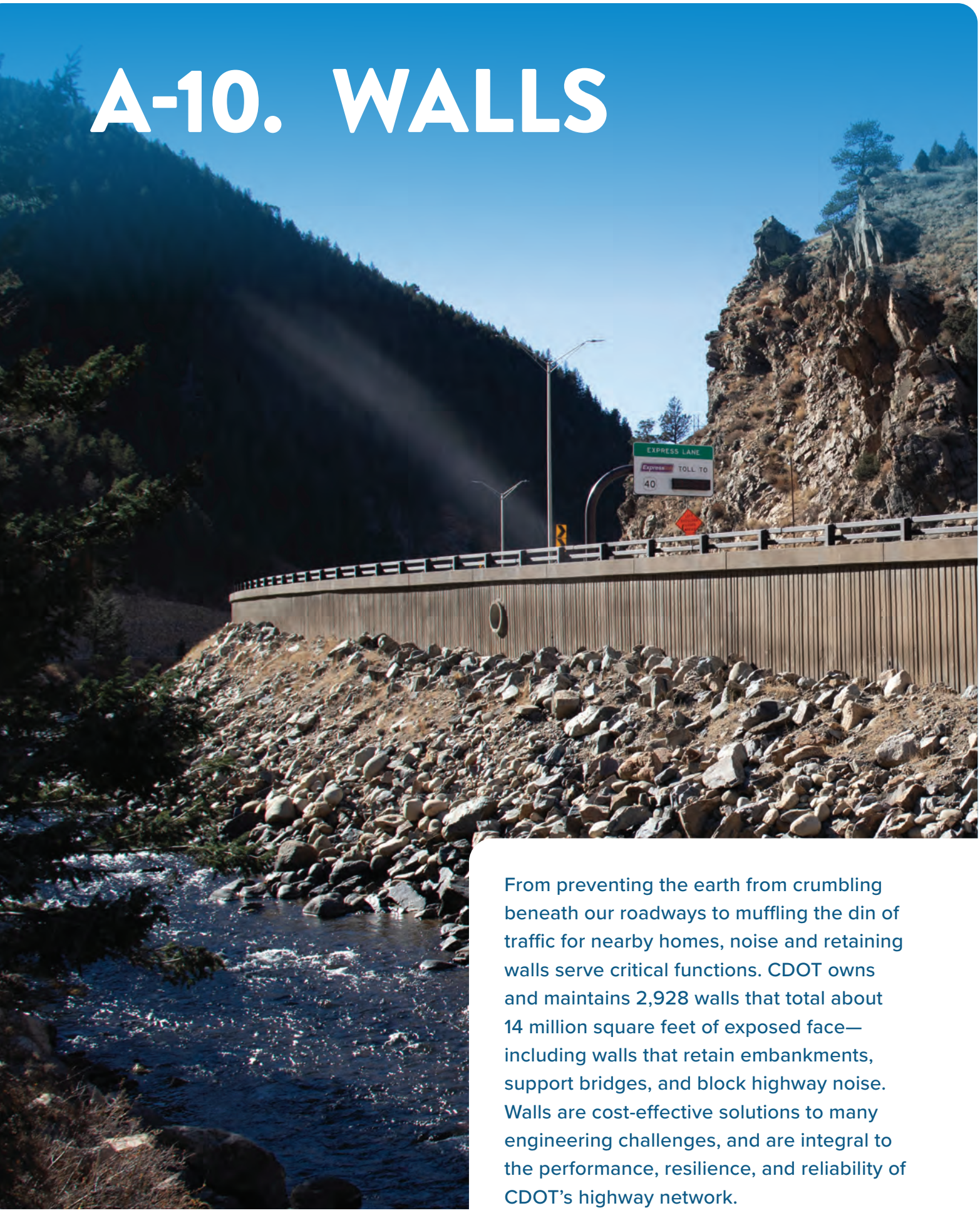
PROCESS

Process improvement is a key aspect of managing the Tunnels program. Staff will be working in the near term on further defining the roles and relationship between the tunnels asset management program and the Bridge and Tunnel Enterprise.

TECHNOLOGY AND ANALYSIS CAPABILITIES

Future analysis improvements include developing a stronger network-level forecasting capability via the AIMS asset model.

A-10. WALLS



From preventing the earth from crumbling beneath our roadways to muffling the din of traffic for nearby homes, noise and retaining walls serve critical functions. CDOT owns and maintains 2,928 walls that total about 14 million square feet of exposed face—including walls that retain embankments, support bridges, and block highway noise. Walls are cost-effective solutions to many engineering challenges, and are integral to the performance, resilience, and reliability of CDOT's highway network.

CDOT's Staff Bridge Branch manages retaining walls that are at least four feet tall and within 45 degrees of being vertical and noise walls that are at least eight feet tall. This work is undertaken through the retaining and noise wall inspection and asset management program (Walls program). CDOT walls are managed in alignment with the CDOT asset-management process described in the Introduction to the Asset Plans Appendix. Since 2016, CDOT's wall conditions have remained relatively constant and have been close to achieving the Department's performance target. However, the current funding level is not expected to sustain this level of performance for the next 10 years. Achievement of the desired conditions is expected to require additional funding.

Figure A.10-1 *Wall Assets at a Glance*

PERFORMANCE MANAGEMENT

CDOT manages and monitors the performance of walls through quantitative performance measures and an overall target. The Department uses this performance data to inform funding decisions and track the condition and relative risks for each wall.

POLICY DIRECTIVE 14.0 PERFORMANCE MEASURE

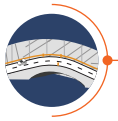
The asset management program for walls contributes to the Policy Directive 14.0 (PD 14.0) goal areas of asset management, safety, and mobility. To determine wall conditions, CDOT's walls are inspected following the same methodology detailed by the National Bridge Inspection Standards (NBIS) and receive Good, Fair, or Poor ratings. The specific performance measure for walls is the percentage of CDOT-owned walls, by square foot, in Poor condition (that is, with a rating of 4 or less). The PD 14.0 target is set at or below 2.5 percent of Poor wall area. The process for assessing condition is described in the Inventory and Condition section of this Asset Plan. **Table A.10-1** presents the PD 14.0 target and 2021 performance for walls.

OTHER PERFORMANCE MEASURES

In addition to condition rating, CDOT identifies Essential Repair Findings during inspections. Essential Repair Findings are deficiencies that can compromise the ability of the structure to safely remain in place and are deemed as requiring immediate identification, notification, correction, and follow-up.

Table A.10-1 *CDOT Asset Management Metric and Performance Target for Walls*

WALLS



Measure	Target	2021 Performance
Percent (by square feet) in Poor condition	≤2.5%	3.5%

For federal TAMP purposes, CDOT defines the state-of-good-repair for walls based on the measures presented in PD 14.0.

INVENTORY AND CONDITION

CDOT's wall inventory and condition information is collected through the Walls program, which is managed by the Bridge and Structure Inspection Unit within the CDOT Staff Bridge branch. CDOT hires consultants to perform field inspections of walls and enter inspection data into the System for Asset Management and Inspection (SAMI). SAMI consists of a Web-based data-management and reporting platform and a mobile-inspection application. The Bridge and Structures Asset Management Unit within the Staff Bridge branch is responsible for data management and reporting of the inspection data from SAMI.

INVENTORY

As of 2021, CDOT owns and maintains 2,928 walls totaling approximately 14 million square feet of exposed face, as presented in **Table A.10-2**. Walls are constructed with materials including concrete, steel, and timber. Materials vary based on application, desired aesthetics, and cost. **Figure A.10-2** provides example photographs of different wall types that CDOT manages.

CDOT's inspection and asset management program for walls includes retaining walls that are at least four feet tall and within 45 degrees of being vertical and noise walls that are at least eight feet tall. This program excludes common walls like:

- Traffic barriers less than four feet tall.
- Slope protection that is more than 45 degrees from vertical.
- Rock slope stabilization such as mesh, netting, anchors, or soil nails.

Additional details on the criteria and features for walls inspected by CDOT can be found in CDOT's *Retaining and Noise Wall Inspection and Asset Management Manual.*[1]

Table A.10-2 *Inventory of Wall Assets*

Wall Type	Current Count	Area (Square Feet, in Millions)
Retaining Wall	2,303	9.0
Bridge Wall	268	0.8
Noise Wall	357	4.2
Total Count	2,928	14.0

Figure A.10-2 *Photographs of Retaining, Bridge, and Noise Walls*

Retaining Wall

Bridge Wall

Noise Wall

1 Retaining Noise Wall Inspection and Asset Management Manual

ASSET HIERARCHY

CDOT tracks the condition and/or functionality of the major elements that comprise each wall to better understand its performance. **Table A.10-3** provides an overview of the categories of walls and their respective construction types, elements, and materials.

Table A.10-3 *Asset Hierarchy*

	Structure Type	Common Construction Types	Elements	Typical Materials
	Retaining Wall	» Cantilever » Mechanically Stabilized Earth » Soil Nail » Bin	» Wall Facing » Footing » Caisson » Anchor » Coping » Weep Hole	» Timber » Masonry » Concrete » Steel
	Bridge Wall	» Mechanically Stabilized Earth » Cantilever	» Wall Facing » Footing » Pile » Anchor » Coping » Weep Holes	» Concrete » Masonry
	Noise Wall	» Post and Panel » Free Standing on Footing or Leveling Pad	» Wall Facing » Caisson » Vertical Supports	» Timber » Masonry » Concrete

CONDITION

CDOT's Walls program inspects all walls following the same methodology detailed by the National Bridge Inspection Standards for both component and element-level data. There is no federal mandate for the inventory and inspection of retaining or noise walls. CDOT Staff Bridge policy is that routine inspections for both retaining and noise walls be performed at a maximum interval of six years, and the maximum inspection interval for bridge walls should not exceed four years. Certain structures, deemed higher risk by the inspector, may require shorter inspection intervals.

Inspectors rate the wall's overall condition on a scale of 0 to 9, in which 0 represents a failed wall and 9 represents a wall in excellent condition. Inspectors also identify the condition states of individual elements on a scale from 1 to 4, in which 1 represents an element in Good condition, and 4 represents an element in Severe condition. While both sets of scores are collected and stored in SAMI, currently only the 0 to 9 overall condition scale is used for planning, performance management, budgeting, and project prioritization.

Using the overall condition rating, walls are categorized as being in Good, Fair, or Poor condition based on the numeric rating, as shown in **Figure A.10-3**. The definitions for these ratings can be found in CDOT's *Retaining and Noise Wall Inspection and Asset Management Manual*.

Figure A.10-3 *Overall Wall Condition Rating Scale*

In addition to numerical condition ratings, inspectors identify deficiencies that can compromise the ability of a wall to safely remain in place and are deemed as requiring immediate identification, notification, correction, and follow-up. These deficiencies are noted as Essential Repair Findings. Common causes of Essential Repair Findings include freeze-thaw damage on mechanically stabilized earth walls; bulging, rotation, or separation of wall panels; and failure of timber noise walls. Inspectors identify approximately 10 Essential Repair Findings for walls each year.

CONDITION TRENDS

As of 2021, CDOT owns and manages 14 million square feet of wall area. Out of these, 13.1 million square feet (96.5%) are in Fair or Good condition, as presented in **Table A.10-4**, and there were 15 open Essential Repair Findings on the state highway system. The percent of Good, Fair, and Poor walls has remained fairly constant since 2016.

ASSET VALUE

CDOT undertook an assessment of asset value in 2022 for this document. The current replacement value of walls is determined by using a unit cost for wall surface area. This replacement value is $4.9 billion.

To calculate current asset value, the replacement value is adjusted by the condition rating. The current value of wall assets is $3.5 billion.

Table A.10-4 *Wall Condition Trends*

Total Area (sq. ft. in millions)	Year	% in Fair or Good Condition	Essential Repair Findings
14.0	2021	96.5%	15
13.6	2020	96.2%	3
12.9	2019	95.8%	21
12.8	2018	95.8%	3
10.1	2017	96.7%	7
10.1	2016	95.8%	19

LIFE-CYCLE PLANNING

CDOT analyzes its wall inventory and inspection data to forecast investment needs and set work priorities. This process is known as life-cycle planning and accounts for the whole-life costs of planning, constructing, and maintaining walls, with consideration for minimizing long-term costs while preserving or improving the condition. Currently, the main driver for applying life-cycle strategies to wall assets is condition. CDOT leverages the findings from its annual condition-assessment report and employs various treatments to address the needs of walls in different conditions. Major rehabilitation and reconstruction restore walls that are identified as Essential Repair Findings or in Poor condition. Walls in Good and Fair condition receive routine maintenance, as needed.

LIFE-CYCLE PLANNING

CDOT uses a condition-based approach to the life-cycle management of a wall. This means condition data is used to determine the appropriate type and timing of work and to prioritize potential work within available budgets. CDOT identifies damaged walls that diminish the resiliency and reliability of the highway system and prioritizes these assets. Impacts of poorly functioning walls on CDOT's highway system are discussed in the section named Impacts of Insufficient Funding. CDOT prioritizes wall projects for maintenance to minimize such safety, mobility, environmental, public perception, public health, and asset management risks.

The Walls program maintains, repairs, rehabilitates, and replaces walls. Some design work is performed in-house, but most construction is performed by contractors. CDOT's Maintenance Levels of Service (MLOS) program delivers routine maintenance, preservation treatments, and repairs that do not require engineering.

The current program approach for managing wall assets is typically reactive in nature. CDOT's wall-maintenance program prioritizes addressing walls that pose substantial risks, (i.e., are identified with Essential Repair Findings). As a result, most repairs and wall maintenance are carried out in response to inspection findings. Examples of inspection findings requiring repair include deterioration due to water, vehicle-impact damage, or observed deterioration reported by maintenance staff or periodic inspections.

PROGRAM DECISION-MAKING

CDOT uses several different treatments to address wall deterioration. Wall treatments can range from vegetation removal to patching or replacement, depending on the wall condition and availability of funds. Definitions of the wall treatment work types are summarized below. A list of wall treatments and their approximate costs are shown in **Table A.10-5**.

- **Preservation** consists of activities that prolong the life of the structure without changing the condition rating (i.e., preventative maintenance). Examples include vegetation removal and drainage cleanout.
- **Maintenance** includes patching and other repair treatments that do not have the potential to change condition but provide an expected extension of service life.
- **Rehabilitation** includes repairs or replacements of portions of walls that provide a change in wall condition and expected extension of service life. Examples include replacing deteriorated blocks, resetting bulging or rotated concrete panels, or patching extensive cracks or spalls.

» **Reconstruction** consists of replacing the existing structure with a new structure. This results in a resetting of wall condition and service life expectations. Typically, walls are not replaced in full unless the structure has failed somewhere along its length.

» **Initial Construction** consists of building a structure where no structure has ever been built.

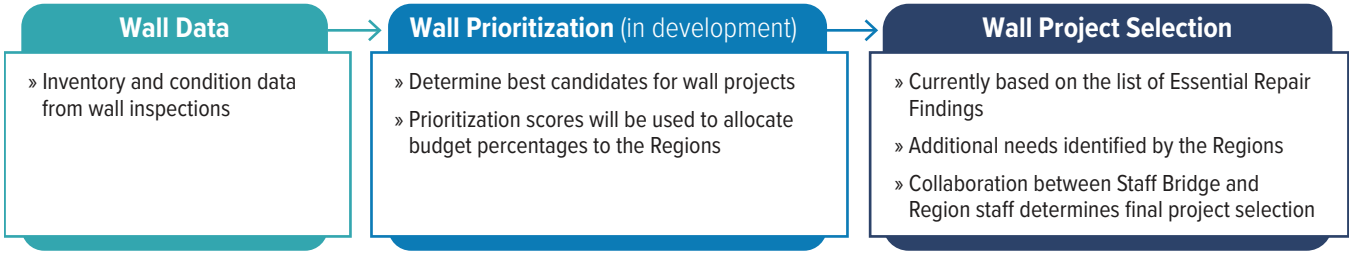
Table A.10-5 *Wall Life-Cycle Management Activities*

FHWA Treatment Work Type	Activity	Typical Costs/Square Foot
Preservation	Vegetation Removal	$15
Maintenance	Patching	$180
Rehabilitation	Replacing Deteriorated Blocks	$250
Reconstruction (Replacement)	Replacement	$300

TREATMENT SELECTION

Regions are provided with a prioritized list of walls annually, which helps them identify wall projects for that year. Projects are typically chosen from the open list of Essential Repair Findings. **Figure A.10-4** presents the project prioritization and project-selection process for walls.

Figure A.10-4 *Walls Project-Prioritization and Selection Process*



RISK MANAGEMENT

The Walls program manages risk across multiple levels—agency, programmatic, and project/asset. Section 6 of the main TAMP document provides more information about CDOT's risk-management methodology and processes.

The Walls program maintains a register of risks to its overall program and projects. Top risks are presented in **Table A.10-6**.

Table A.10-6 *Top Walls Risks*

Risk Level	Threat / Opportunity	Risk Score[2]	Risk-Management Strategy
Project	Catastrophic failure—mobility and safety impacts	20 (T)2 x (C)5 x (V)2	Treat
Project	Non-catastrophic failure—no mobility impacts	7.5 (T)1 x (C)2.5 x (V)3	Tolerate

2 Risk Score = Threat Likelihood (T) * Total Consequence and Consideration Score (C) * Vulnerability (V)

FINANCIAL PLAN

CDOT establishes annual planning budgets for walls and other asset programs four years in advance. Estimates of revenue and costs for meeting performance targets are combined with CDOT's life-cycle management approaches to inform decisions on the planning budget (financial plan). Delivery of the planning budget will contribute to CDOT's efforts to achieve system-wide asset performance goals.

FUNDING SOURCES

The Walls program receives a portion of the funds of CDOT's overall Transportation Asset Management (TAM) program to fund rehabilitation and reconstruction work types described in the Life-Cycle Planning section. Of this base funding, about $1 million per year is used for inspections.

Meanwhile, preservation and maintenance provided by the Maintenance Levels of Service (MLOS) program is budgeted separately, in the MLOS Financial Plan. While the Walls and MLOS programs provide this base funding, wall projects can be funded by a variety of sources and programs.

PLANNED FUNDING

Table A.10-7 summarizes the projected funding levels for walls for the next 10 years. These estimates include $1 million per year for inspections.

Table A.10-7 *Financial Plan for Walls (in Millions)*

FY22	FY23	FY24	FY25	FY26	FY27	FY28	FY29	FY30	FY31
$5.4	$5.8	$5.7	$5.7	$5.7	$5.7	$5.7	$5.7	$5.7	$5.7

INVESTMENT STRATEGIES

CDOT forms investment strategies based on its financial plan and life-cycle management strategies identified to achieve system-wide asset performance goals while minimizing life-cycle costs. The investment strategies delineate different types of work to be performed across CDOT's wall assets over a 10-year period.

BACKGROUND: DETERMINING INVESTMENT STRATEGIES

Investment strategies for managing walls are focused on minimizing the risk of failure (described in the Life-Cycle Planning section of this Asset Plan). For each damaged wall CDOT generates a list of treatment strategies. These strategies are composed of repair, rehabilitation, and replacement treatments for each wall, based on the annual condition-assessment report. CDOT prioritizes walls identified as Essential Repair Findings or in Poor condition for major rehabilitation work. Walls in Fair or Good condition receive routine maintenance, as budget permits.

PLANNED INVESTMENTS

Structures with one or more Essential Repair Findings are given a higher priority for programming for treatment. About 10 walls with such findings are programmed each year.

Maintenance and Repair. CDOT's maintenance crews conduct routine maintenance, preservation treatments, and repairs for walls that do not require engineering. Those activities are part of the Maintenance Levels of Service (MLOS) asset plan and its financial plan and investment strategy.

Rehabilitation, Reconstruction, and Replacement. CDOT's Walls program performs routine inspection, repair, rehabilitation, reconstruction, and replacement of walls that are not covered under the MLOS program. These activities are part of the Walls program and its financial plan and investment strategy.

PERFORMANCE GAP ANALYSIS

CDOT uses its Asset Investment Management System (AIMS) model to develop its annual forecast for the performance of wall assets and any anticipated performance gaps. The results of the AIMS analysis inform the financial plan for the asset class. Based on the most recent analysis, current funding will not allow CDOT to achieve its performance target for walls. CDOT's ability to close performance gaps largely depends on receiving additional funding.

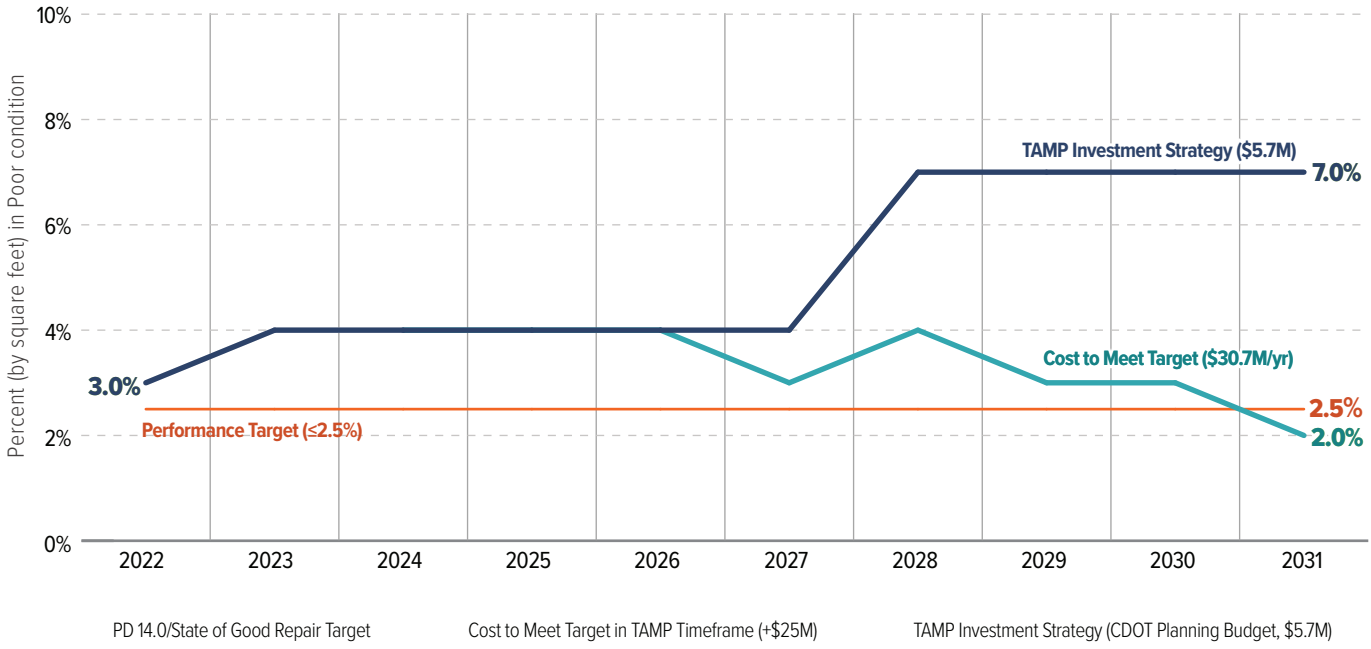
NEEDS AND PROJECTED CONDITION

CDOT's AIMS model predicts the long-term performance of wall assets, as constrained by the financial plan for the asset class. The model projects condition ratings for walls using deterioration assumptions developed in 2016. Additionally, the model accounts for planned walls projects for the early years of the analysis, when many projects are known. For later years, the model recommends projects, as constrained by anticipated budgets.

The financial plan of investing $5.7 million per year in walls does not provide sufficient funding to meet the established PD 14.0 performance target, as presented in **Figure A.10-5**. At least an additional $25 million annual investment is required to achieve the performance target in the next 10 years.

Figure A.10-5 *Forecast of Wall Assets Performance*

The anticipated annual budget of $5.7 million will not meet the performance target of ensuring that less than 2.5% of wall area is in poor condition. The annual cost of meeting the target by 2031 is about $30.7 million, or an additional $25 million per year.



IMPACTS OF INSUFFICIENT FUNDING

Walls are crucial to the resiliency of CDOT's highway system. As a result of insufficient funding, the following outcomes may occur.

- **Safety and Mobility:** Damaged retaining walls that support roadways can reduce the roadway integrity and create risks of highway failure, resulting in partial or complete closures and subsequent detours. In the extreme case, a failed wall could pose a direct safety risk to highway users or local residents.
- **Public Perception:** Noise walls and many retaining walls are visible to the traveling public. Damaged and deteriorating walls could negatively impact CDOT's public image. Damaged or failed noise walls can increase the noise and emissions pollution experienced by residential areas near the highway system.
- **Asset Management:** Even small variations in funding levels can affect the long-term condition of walls. Failure to perform routine preventative maintenance results in more extensive or earlier rehabilitation treatments.
- **Public Health:** Prolonged exposure to loud noise can lead to a wide array of health concerns, such as high blood pressure, heart disease, sleep disturbances, and stress. Noise walls reduce or lessen the likelihood of these impacts.
- **Environmental:** Environmental benefits of retaining walls and bridge walls include erosion control and flood control, as well as reducing the footprint of the right of way (ROW).

OPPORTUNITIES TO CLOSE THE GAP

CDOT regularly evaluates investment strategies and funding levels to determine the best strategy to meet condition targets. Based on such reviews—which include a review of the current life-cycle planning approach—CDOT determines which issues lead to accelerated wall deterioration and prioritizes wall projects accordingly. CDOT may alter its existing strategy by adjusting treatments, condition targets, and other factors to help close performance gaps.

CDOT also analyzes funding relative to targets at the TAM Oversight Committee's annual budget-setting workshop for asset management. The Staff Bridge team can adjust funding recommendations, as well as treatment recommendations and priorities, to address targets. Staff Bridge also works with CDOT's Regions to understand funding that is used from outside the TAM budget to improve wall conditions. Additionally, the Transportation Commission is briefed each year on performance versus targets in PD 14.0 and may adjust funding to address gaps.

The Life-Cycle Planning and Investment Strategies sections of this Asset Plan describe the high-level CDOT investment strategies and methods for closing performance gaps for walls.

STRATEGIC USE OF ADDITIONAL REVENUE

Should CDOT receive additional revenue to fund the Walls asset class, the Department's first priority is to eliminate any funding gaps related to achieving the PD 14.0 performance target. Once goals are achieved, the Department will reduce Poor backlog with a priority towards the most critical and/or vulnerable assets to improve system resilience. CDOT estimates the current "Poor" backlog for Walls could be eliminated with about $216 million.

FUTURE IMPROVEMENTS

Planned asset management improvements to the Walls program focus on processes and technology.

PROCESS

Process improvement is a key aspect of maintaining and improving the Walls program and assets. CDOT intends to improve the accurate capture of inventory data and the Department's ability to track the condition and disposition of these assets over time.

CDOT aims to shift from risk-based, reactive wall management that emphasizes emergency repairs to a more proactive approach with a long-term view of the condition of the walls network. A more proactive approach would enable CDOT to focus on preservation, rehabilitation, and replacement before emergency repairs are needed. This more proactive approach is expected to reduce the life-cycle cost and minimize disruption.

The Department's updated wall-treatment prioritization program is in development, with the goal of using multi-objective prioritization to determine best candidates for wall projects and to allocate budget percentages to the Regions. One aspect of the planned approach involves routine maintenance activities intended to preserve wall assets and slow deterioration rates to obtain the anticipated life cycle.

TECHNOLOGY AND ANALYSIS

Similar to Bridges, SIMSA software will incorporate wall assets and will:

- Consolidate wall data (e.g., condition, inventory) for easy access and use throughout the Department, including serving as a platform to upload and access "as-built" plans.
- Streamline wall inspection and inventory data collection and review for more accurate, up-to-date information.
- Integrate with CDOT's AIMS model so that data uploads (e.g., new condition and inventory data) to the model are easier than in the past.

These process improvements would integrate more robust asset management practices into the Walls program and improve the forecasting capabilities of the AIMS asset model.

APPENDIX B. **POLICY DOCUMENTS**

COLORADO
Transportation Commission

RELEASE MEMORANDUM

TO: All CDOT Employees

FROM: Natalie Lutz, Rules, Policies, and Procedures Administrator
Herman Stockinger, Transportation Commission Secretary

RE: New Policy Directive 1609.0 "Transportation Asset Management"

DATE: February 4, 2021

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1. Name of New Policy Directive:
   Policy Directive 1609.0 "Transportation Asset Management"

2. Date of Policy Directive this Directive Supersedes: New

3. Executive Summary:
   On January 21, 2021, the Transportation Commission adopted the new Policy Directive 1609.0 "Transportation Asset Management" to articulate existing practices and processes of the Colorado Department of Transportation's (Department) Transportation Asset Management (TAM) program. The Policy Directive provides a high-level description of the TAM program, such as key definitions, principles, requirements for asset classes, a list of the program's asset classes, key program functions, and citations of related CDOT Policy Directives.

   The purpose of asset management is "to achieve and sustain a state of good repair for Department assets over their life cycles at a minimum practicable cost."[1] The TAM program maintains 12 asset classes (e.g., bridges, pavement, culverts). The Policy Directive states that the addition or removal of an asset must be approved by the Transportation Commission. The Policy Directive continues by outlining key functions of the TAM program, including developing planning budgets and a four-year program of asset treatments (e.g., asset replacements, rehabilitations, preventive maintenance activities, etc.). The Transportation Commission ultimately adopts the planning budgets for the assets by resolution. Finally, the Policy Directive describes federal asset management requirements and related federal law and regulations.

4. Offices to Contact with Questions:
   The Office of Policy and Government Relations at: 303.757.9441 or natalie.lutz@state.co.us
   The Performance and Asset Management Branch at: 303.757.9815 or toby.manthey@state.co.us

5. Effective Date of New Policy Directive: January 21, 2021

[1] *This approach aligns with the purpose of asset management in 23 CFR 515.9.*

COLORADO DEPARTMENT OF TRANSPORTATION	X POLICY DIRECTIVE ☐ PROCEDURAL DIRECTIVE

Subject **Transportation Asset Management**		**1609.0**
Effective **01.21.21**	**Supersedes** **New**	**Originating Office** **Division of Transportation Development** **Transportation Asset Management Program**

I. PURPOSE

The purpose of this policy directive is to describe the structure, key functions and principles of the Transportation Asset Management ("TAM") program at the Colorado Department of Transportation ("CDOT" or the "Department"). The directive also defines key terms used in the program.

II. AUTHORITY

§ 43-1-106(8)(a), C.R.S. Colorado Transportation Commission ("Commission")

23 CFR § 515, *Asset Management Plans*

23 CFR § 490, *National Performance Management Measures*

III. APPLICABILITY

This policy directive applies to all CDOT employees and to all Asset Classes within the TAM program.

IV. DEFINITIONS

"Asset" means a physical object that is part of CDOT's infrastructure; for example, a road, bridge, culvert, tunnel, or wall.

"Asset Class" generally means a set of fixed assets having similar characteristics and attributes that differentiate them from other assets by kind, type, or function. There are twelve (12) asset classes in CDOT's TAM program. "Asset class" can also refer to a program whose activities maintain other infrastructure (e.g., Geohazards or Maintenance Levels of Service).[1]

"Asset Management" refers to a strategic and systematic process of operating,

[1] *CDOT's Maintenance Levels of Service (MLOS) program is considered an asset class due to the close relationship of maintenance activities and the condition of pavement, bridges and other assets. The program also helps fund the replacement of maintenance assets such as signs, striping, delineators and fencing. Similarly, the Geohazards program funds activities that protect other assets, such as pavement, while also maintaining geohazards assets such as rockfall fencing.*

maintaining, upgrading, and replacing physical assets effectively throughout their life cycle. It focuses on business and engineering practices for resource allocation and utilization, with the objective of better decision making based upon quality information and well-defined objectives.[2]

"Planning Budget" refers to the budget levels planned for each asset in future years, before they become actual budgets. These levels are typically set four years in advance.

"Transportation Asset Management Cap ("TAM Cap")" means the sum of the annual planning budgets for all assets in the TAM program.

"Transportation Asset Management Plan ("TAMP")" refers to a document required by the Federal Highway Administration ("FHWA") that includes asset performance measures, a financial plan, and other elements as described in federal law and regulation. The TAMP is designed to help improve or preserve the condition and performance of assets on the highway system.

"Transportation Asset Management ("TAM") program" means a specific collection of CDOT asset programs that meet established criteria and help manage CDOT's critical infrastructure assets. The program is coordinated by CDOT's Division of Transportation Development ("DTD"). Individual asset classes are managed by various work units throughout the Department.

V. POLICY

A. CDOT TAM Principles and Purpose

The purpose of asset management is "to achieve and sustain a state of good repair for Department assets over their life cycles at a minimum practicable cost." [3] This approach assists CDOT in pursuing its mission by maintaining assets comprising the transportation system, ensuring the system is effective and safe.

The asset-management program focuses on maintenance, asset preservation and replacement. The program does not fund projects that increase the capacity of Colorado's transportation system.

B. Requirements for Asset Classes

Asset Classes in the TAM program must meet criteria including the following:

1. Each Asset Class must maintain an inventory of its assets.

[2] *This passage is based on a definition from the American Association of State Highway and Transportation Officials.*

[3] *This approach aligns with the purpose of asset management in 23 CFR 515.9.*

2. Each Asset Class must maintain a performance metric (e.g., "Good," "Fair" and "Poor" condition ratings for bridges, or letter grades for buildings and rest areas.)
3. Each Asset Class must provide a target for their performance metric.
4. Each Asset Class must maintain an asset management system. These systems should have, at minimum, the ability to forecast condition; the ability to inform the selection of a performance target; and the ability to minimize the cost in achieving that performance target by recommending treatments or activities.
5. Each Asset Class must be able to distinguish annual maintenance activities, capital preservation, replacement activities, and expansion projects. Asset Classes should only fund annual maintenance, capital preservation and replacement activities.

C. Asset Classes in the TAM program:

The Commission has approved 12 Asset Classes in the TAM program and shall give final approval to the addition or removal of any Asset Class from the program. The 12 asset classes include:

1. Bridges
2. Buildings
3. Culverts
4. Geohazards
5. Intelligent Transportation Systems ("ITS")
6. Maintenance Levels of Service ("MLOS")
7. Pavement
8. Rest Areas
9. Road Equipment (Fleet)
10. Signals
11. Tunnels
12. Walls

D. Establishing TAM Planning Budgets and Approving Treatment Lists

Primary functions of the TAM program include establishing the following:

1. TAM Cap:
    a. The total dollars dedicated to the TAM program for a given fiscal year. Typically set four years in advance.
2. Planning Budget:
    a. The portion of the TAM Cap allocated for each Asset Class. Typically set four years in advance.

3. Treatment lists:
    a. Each Asset Class in the TAM program, except for MLOS, develops an annual list of treatments (e.g., asset replacements or rehabilitations). Treatments are typically submitted four years in advance and ultimately become standalone projects or are bundled by staff into projects that may encompass multiple treatments.

Both the TAM Cap and the planning budgets are developed by staff and adopted by resolution of the Commission. Treatment lists are developed by staff and are approved by CDOT executive management. The TAM Cap, Planning Budgets, and treatment lists are typically set four years in advance to provide predictability to CDOT's Transportation Regions and to construction stakeholders. Knowing the Planning Budgets four years in advance gives CDOT staff the time to plan, develop, and design projects, so that when the year arrives for construction funding to be allocated, projects are ready to be delivered.

The Commission supports CDOT's adherence to a procedural directive that outlines how the TAM Cap and the planning budgets are developed, and how treatment lists are approved and modified.

E. Asset Performance Metrics
    1. The Commission has adopted PD 14.0 ("Policy Guiding Statewide Plan Goals & Objectives") to measure the success of the Department's efforts to improve in asset management and other goal areas. Performance targets for each Asset Class in the TAM program can be found in Appendix A of PD 14.0. The performance targets help implement the Statewide Transportation Plan by focusing transportation investments in the Statewide Transportation Improvement Program (STIP) and the annual budget.

F. Federal Asset Management Requirements
    1. National Performance Measures for National Highway System ("NHS") pavement and bridge assets.

        CDOT must comply with federal requirements (see 23 CFR § 490) to track and periodically report performance measures for NHS pavement and bridges and to periodically set targets for those measures. These metrics include:

        a. The percentage of Interstate pavements in good condition, and the percentage in poor condition.

b. The percentage of non-Interstate NHS pavement in good condition, and the percentage in poor condition.
c. The percentage of NHS bridge deck area in good condition, and the percentage in poor condition.

States not meeting minimum condition levels for the bridge metrics, and the pavement metrics for Interstates, face penalties regarding their use of federal transportation funds, such as National Highway Performance Program funds.

2. Transportation Asset Management Plan (TAMP).

CDOT must comply with federal requirements (see 23 CFR § 515) to produce a Transportation Asset Management Plan (TAMP) or face penalties regarding the Department's use of National Highway Performance Program funds. The plan must include a summary listing of NHS pavement and bridge assets in Colorado, regardless of ownership. The plan must span at least 10 years and must include investment strategies, a financial plan, and other elements described in federal code. The Federal Highway Administration (FHWA) requires the plans to be updated at least every four years.

G. Risk Policy Directive

For a description of CDOT's approach to risk, including for asset management, see Policy Directive 1905.0—*Building Resilience into Transportation Infrastructure and Operations.*

H. Approving Final Asset Management Budgets and Project Changes

For processes related to approving final[4] asset management program budgets and budget changes to asset management projects, see Policy Directive 703.0—*Annual Budget, Project Budgeting, and Cash Management Principles.*

VI. DOCUMENTS RELEVANT TO OR REFERENCED IN THIS POLICY DIRECTIVE

Policy Directive 14.0—*Policy Guiding Statewide Plan Goals & Objectives*

Policy Directive 703.0—*Annual Budget, Project Budgeting, and Cash Management Principles*

[4] *"Planning" budgets for asset management programs are adopted by the Commission, as mentioned earlier in this directive (1906.0). Planning budgets do not become final budgets for those programs until approved by the Commission as part of CDOT's Annual Budget.*

Policy Directive 1905.0—*Building Resilience into Transportation Infrastructure and Operations*

23 CFR § 515—*Asset Management Plans*

23 CFR § 490—*National Performance Management Measures*

VII. IMPLEMENTATION PLAN

This Policy Directive shall be effective upon signature.

The Office of Policy and Government Relations shall post this Policy Directive on CDOT's intranet as well as on public announcements.

VIII. REVIEW DATE

This directive shall be reviewed on or before January 2026.

Herman F. Stockinger III
Herman Stockinger
Transportation Commission Secretary

1/21/2020
Date of Approval

Resolution #TC-2021-01-07

Adoption of New Policy Directive 1609.0 "Transportation Asset Management".

Approved by the Transportation Commission on January 21, 2021.

WHEREAS, § 43-1-106 (8)(a) C.R.S. gives authority to the Transportation Commission of Colorado ("Commission") to formulate general policy with respect to the management, construction, and maintenance of public highways and other transportation systems in the state; and

WHEREAS, new Policy Directive 1609.0 "Transportation Asset Management" establishes the guiding framework of the Transportation Asset Management Program within the Colorado Department of Transportation ("Department"); and

WHEREAS, the purpose of asset management is to achieve and sustain a state of good repair for the Department's assets over their life cycles at a minimum practicable cost; and

WHEREAS, asset management is a strategic and systematic process of maintaining assets comprising the transportation system and ensuring the system is effective and safe; and

WHEREAS, the Department maintains twelve (12) Asset Classes in the Transportation Asset Management Program, which include: Pavement, Bridges, Tunnels, Buildings, Road Equipment, Intelligent Transportation Systems, Rest Areas, Culverts, Walls, Signals, Maintenance Levels of Service, and Geohazards; and

WHEREAS, the Department must comply with federal requirements to track and periodically report performance measures for National Highway System pavement and bridges as set forth in Policy Directive 14.0 "Policy Guiding Statewide Plan Goals & Objectives"; and

WHEREAS, federal law requires the Department to develop a risk-based asset management plan for the National Highway System to improve or preserve the condition of the assets and the performance of the system; and

WHEREAS, the Commission supports the Department in pursuing its mission by efficiently allocating the Department's resources across assets to maintain a high quality and safe system in compliance with federal law and regulations.

NOW THEREFORE BE IT RESOLVED, the Commission adopts the new Policy Directive 1609.0 "Transportation Asset Management".

Herman F. Stockinger III

Herman Stockinger, Secretary
Transportation Commission of Colorado

1/21/2021

Date

COLORADO
Transportation Commission

RELEASE MEMORANDUM

TO: All CDOT Employees

FROM: Natalie Lutz, Rules, Policies, and Procedures Administrator
Herman Stockinger, Transportation Commission Secretary

RE: Updated Policy Directive 14.0 "Policy Guiding Statewide Plan Goals and Objectives"

DATE: December 14, 2020

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1. Name of Updated Policy Directive:
   Policy Directive 14.0 "Policy Guiding Statewide Plan Goals & Objectives"

2. Date of Policy Directive this Directive Supersedes: October 19, 2017

3. Executive Summary:
   On November 19, 2020, the Transportation Commission adopted the updated Policy Directive 14.0 with revised performance goals and objectives to measure the success of the Department's efforts to improve in safety, asset management, and mobility. The performance goal areas were changed to better guide the implementation of the new multimodal Statewide Transportation Plan. The revised performance goals also support the national goals for surface transportation in the Fixing America's Surface Transportation (FAST) Act of 2015. Objectives in previous goal areas have been realigned into the new goal structure or have been modified.

   Additionally, the updated Policy Directive aligns objectives with other key guiding policies such as the Greenhouse Gas Pollution Reduction Roadmap and HB19-1261 ("Climate Action Plan to Reduce Pollution"). Nine new defined terms were added to support the revised goal areas and other guiding policies, which include: Carbon Dioxide Equivalents, Colorado DOT Transit Asset Management Group Plan, Greenhouse Gas Emissions, State of Good Repair,Telecommuting, Transit Economic Requirements Model, Unlinked Passenger Trips, Vulnerable Users, and Zero-Emission Vehicles. Finally, Appendix "B" for the Department's Transit Asset Management and Appendix "C" for Strategic Transportation Safety Plan (STSP) Tier 1 Strategies were included.

4. Offices to Contact with Questions:
   The Office of Policy and Government Relations at: 303.757.9441 or natalie.lutz@state.co.us.
   The Division of Transportation Development at: 303.757.9133 or darius.pakbaz@state.co.us

5. Effective Date of Updated Policy Directive: November 19, 2020

COLORADO DEPARTMENT OF TRANSPORTATION		■ POLICY DIRECTIVE □ PROCEDURAL DIRECTIVE
Subject **Policy Guiding Statewide Plan Goals & Objectives**		**Number** **14.0**
Effective 11/19/2020	**Supersedes** 10/19/2017	**Originating Office** **Division of Transportation Development**

I. PURPOSE

This Policy Directive provides performance goals and objectives to measure the success of the Department's efforts to improve in the following key areas:

- Safety,
- Asset Management, and
- Mobility.

The performance objectives and targets in these goal areas will help implement the Statewide Transportation Plan by focusing transportation investments in the Statewide Transportation Improvement Program (STIP) and the annual budget. The Transportation Commission will revise this Policy Directive, as needed, with updated performance objectives or targets.

II. AUTHORITY

- 23 United States Code (U.S.C.) 134, 135 and 450, PL 114-94 ("Fixing America's Surface Transportation Act" or "FAST Act")
- 23 Code of Federal Regulations (C.F.R.) Part 420 (Planning & Research Program Administration), 450 (Planning Assistance and Standards), and 490 (National Performance Management Measures)
- § 43-1-106(8)(a), C.R.S. Transportation Commission
- § 43-1-1103, C.R.S. Transportation planning
- Transportation Commission Rules Governing the Statewide Transportation Planning Process and Transportation Planning Regions (2 CCR 601-22; effective September 14, 2018)

III. APPLICABILITY

This Policy Directive applies to all CDOT Divisions and Regions.

IV. DEFINITIONS

"Carbon Dioxide Equivalents (CO_2e)" means the number of metric tons of CO_2 emissions with the same global warming potential as one metric ton of another greenhouse gas, and are calculated using Equation A-1 in 40 C.F.R. Part 98.

"Colorado DOT Transit Asset Management Group Plan" (Group TAM Plan) is the CDOT-sponsored asset management plan, required by the FTA's Transit Asset Management (TAM) Rule, for 49 U.S.C. Chapter 53 funding recipients and subrecipients that own, operate, or

manage capital assets in the provision of public transportation. The Group TAM Plan is a tool for guiding the prioritization of pass-through funds. Approximately 53 small urban and rural transportation providers participate in the current Group TAM Plan to maintain and/or improve the State of Good Repair (SGR) of transit assets.

"Drivability Life" is an indication in years of how long a highway will have acceptable driving conditions based on an assessment of smoothness, pavement distress, and safety. Drivability Life implements traffic based highway categories, and associated category drivability condition standards and allowed pavement treatments. Unacceptable driving condition is specific to each traffic based highway category and means drivers must reduce speeds to compensate for poor conditions, navigate around damaged pavement, or endure intolerably rough rides. The Risk-Based Asset Management Plan identifies three categories of Drivability Life: High (greater than 10 years of Drivability Life remaining); Moderate (4-10 years); and Low (3 or fewer years).

"Greenhouse Gas Emissions" in the scope of this directive refer to pollution from the transportation sector (though these emissions are not exclusive to this sector), and may refer to both start emissions and running exhaust emissions from vehicle tailpipes. These emissions are calculated and expressed in terms of CO_2e. Greenhouse gas or GHG included in this equivalency encompasses carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulfur hexafluoride (SF6), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and other fluorinated greenhouse gases.

"Geohazards" are geologic hazards that affect the transportation system and include debris flow, embankment distress, landslides, rock fall, rockslides, and sinkholes.

"National Highway System" (NHS) is a federally designated system of roadways important to the nation's economy, defense, and mobility. The NHS includes Interstate highways as well as other roadways. Not all NHS roadways are part of the state highway system.

"Maintenance Levels of Service" (MLOS) is a qualitative measure describing operational conditions on the roadway. Overall, Maintenance Levels of Service is a combined grade for nine maintenance program areas. For snow and ice control, the LOS B level includes maintaining high levels of mobility as much as possible, and proactive avalanche control.

"Operations Levels of Service" (OLOS) is a qualitative measure describing operational conditions on the state highway system that is utilized to demonstrate travel-time reliability on the roadway. This measure is calculated during AM and PM weekday peak periods, then aggregated and reported monthly to track year-to-date performance. Operations Levels of Service are travel-time multipliers equated to a grading system of A through F. For example, an OLOS grade of C or better means that the time required to plan for a trip is 1.5 times the free-flow travel time, or less.

"Performance Measures" are the ways that direction towards a goal is measured.

"Performance Objectives" are the specific targets for a performance measure that an organization intends to meet to make progress towards a goal.

"Revenue Service Miles" are the miles operated by transit vehicles when such vehicles are used for providing public transportation and there is an expectation of carrying passengers.

"Serious Injuries" are evident incapacitating injuries that prevent injured persons from walking, driving, or normally continuing the activities they were capable of performing before they were injured in traffic crashes.

"State of Good Repair" (SGR), as defined by the Federal Transit Administration (FTA), is the condition in which a capital asset is able to operate at a full level of performance.

"Telecommuting" is working at home or at an alternate location and communicating with the usual place of work using electronic or other means, instead of physically traveling to a more distant work site, as defined by the Transportation Research Board.

"Transit Economic Requirements Model" (TERM) is the FTA's 5-point scale for subrecipients/transit providers to assess the condition of their transit facilities. A facility assessed below 3.0 is considered to be out of, or beyond, a state of good repair and should be prioritized for repair or replacement.

"Unlinked Passenger Trips" also referred to as 'boardings,' are a measurement of the number of passengers who board public transit vehicles. A passenger is counted each time they board a transit vehicle no matter how many vehicles they use from their origin to their destination.

"Vehicle Miles Traveled" (VMT) are a measurement of miles traveled by vehicles obtained by multiplying the Annual Average Daily Traffic (AADT) count by the length of the roadway segment.

"Vulnerable Users" are pedestrians and bicyclists.

"Zero-Emission Vehicles" are vehicles that produce zero or near-zero exhaust emissions of any criteria pollutant (or precursor pollutant) or greenhouse gas under any possible operational modes or conditions.

V. POLICY

1. Policy. It shall be the policy of CDOT that the Statewide Transportation Plan and statewide performance objectives stated herein will guide distribution of financial resources to meet or make progress toward objectives in three goal areas: safety, asset management, and mobility. The Transportation Commission should direct financial resources toward achieving the safety objectives within the first 4 years of the planning horizon (2021-2024), the asset management objectives within the first 10 years (2021-2030), and the mobility objectives within the first 10 years (2021-2030). Projects should be selected to support the goals and objectives and will be included in the Statewide Transportation Improvement Program (STIP). These performance objectives will guide annual budget decisions. Prior to funding new initiatives, the Transportation Commission will direct funds toward achieving the objectives in each area while recognizing constraints on some funding sources.

2. Goals. PD 14.0 goals guides the implementation of the multimodal Statewide Transportation Plan and the performance objectives that measure attainment of these goals. The goals are:

    - SAFETY – The future of Colorado is zero deaths and serious injuries so all people using any transportation mode arrive at their destination safely.

    - ASSET MANAGEMENT – Maintain a high-quality transportation network by working to maintain a state of good repair for all assets and a highly traversable road network.

    - MOBILITY – Reduce travel time lost to congestion and improve connectivity across all modes with a focus on environmental impact, operations, and transportation choice statewide.

    Goals for PD 14.0 and 2045 Statewide Transportation Plan are in alignment with and complement the national goals for surface transportation in the Fixing America's Surface Transportation (FAST) Act of 2015.

3. Performance Measures and Objectives. Performance measures describe how CDOT will evaluate statewide success, and performance objectives establish statewide achievement levels that are used to direct investment decisions during the different planning horizons for each goal area. Within CDOT's Annual Budget, the budget categories that fund programs within the goal areas are the following: Construction, Maintenance & Operations, Multimodal Programs, Sub-allocated Programs, and Other Programs. Explanations of how the objectives will be measured are listed below with the appropriate goals.

    a) SAFETY:

    The highway safety objectives are aligned with the objectives of the 2020-23 Colorado Strategic Transportation Safety Plan (STSP), an extensive and cooperative planning effort by a multidisciplinary partnership of public agencies, private sector organizations, and advocacy groups representing transportation and safety interests statewide. This collaborative and data-driven process identifies achievable highway safety objectives for the planning horizon of 2021-24. These objectives (with the exception of objectives related to employee safety) apply to *all* roads in the State.

    (1) Highway Safety

    MEASURES:

    - Vehicle crash rate per 100 million vehicle miles traveled (VMT)
    - Traffic fatality rate per 100 million vehicle miles traveled (VMT)
    - Traffic serious injury rate per 100 million vehicle miles traveled (VMT)
    - Traffic fatalities and serious injuries involving vulnerable users (pedestrians and bicyclists)

OBJECTIVES:

- Reduce the rate of vehicle crashes per 100 million VMT by eight percent (8%) over the next four years from current levels.
- Reduce the rate of traffic-related fatalities per 100 million VMT by fifteen percent (15%) over the next four years from current levels.
- Reduce the rate of traffic-related serious injuries per 100 million VMT by fifteen percent (15%) over the next four years from current levels.
- Reduce traffic-related fatalities and serious injuries involving vulnerable users (pedestrians and bicyclists) by fifteen percent (15%) over the next four years from current levels.

ASPIRATIONAL OBJECTIVES:

- Reduce traffic-related fatalities and serious injuries to zero for all users of Colorado's multimodal transportation system.

(2) Employee Safety

MEASURES:

- On-the-Job injuries
- Vehicle crashes involving CDOT Employees

OBJECTIVES:

- CDOT is committed to ensuring a safe and healthy work environment for all of its employees through its fundamental mission of "Excellence in Safety." CDOT also is committed to reducing on-the-job injuries and vehicle incidents involving CDOT employees.

(3) Safety Goal Area Considerations

- The safety goal area and objectives are aligned with the Colorado Strategic Transportation Safety Plan (STSP). Additionally, CDOT and the Transportation Commission support implementation of the STSP Tier 1 strategies. (See Appendix C for explanation of the Tier 1 strategies.)
- In addition to the statewide (all roads) metrics, Staff will provide annually to the Transportation Commission additional highway safety data. Examples include:
  - Urban and rural safety data
  - Safety data on the state highway system
  - Safety data for freight transportation
- CDOT and the Transportation Commission provide the lead on transportation safety efforts in Colorado.

b) <u>ASSET MANAGEMENT:</u>

The asset management objectives for highway related assets are intended to be achieved or maintained over the first ten years of the planning horizon (2021-30). The

objectives identified align with the Department's Risk-Based Asset Management Plan, a federally-required plan that outlines risk-mitigation, identifies performance gaps, and lists a financial plan over the planning horizon. Additionally, the objectives related to highway asset management are used to help determine funding levels for each of the twelve assets within CDOT's asset management program.

The majority of transit assets in Colorado are not owned, operated, or maintained by CDOT. Rather, CDOT passes through federal and state funds to assist subrecipients with transit asset acquisition, construction, and refurbishment projects. Thus, it is the Department's responsibility to oversee subrecipients' participation in the required planning and reporting processes, to guide the prioritization of pass-through funds to maintain and/or improve the state of good repair of transit assets, and to fulfill annual reporting and targeting requirements.

Performance measures and objectives for transit assets were established by the Federal Transit Administration (FTA) in its 2016 Transportation Asset Management (TAM) Rule and incorporated into the 2018 Group TAM Plan. As required, the Group TAM Plan covered a four-year planning horizon and will be updated no later than the fall of 2022. The TAM Rule also outlined annual reporting requirements about the state of good repair of transit assets and requires CDOT, as the Group TAM Plan sponsor, to set annual performance targets across several asset class types. See Appendix B for a more detailed discussion of this process.

The CDOT-owned Bustang and Bustang Outrider fleet vehicles (operated by subrecipients/contractors) are not subject to the TAM Rule reporting requirements but Staff will use the FTA performance measures for consistency in tracking and reporting.

(1) Highway Pavement

MEASURES:

- Pavement condition of the Interstate System
- Pavement condition of the National Highway System (NHS), excluding Interstates
- Pavement condition of the state highway system

OBJECTIVES:

- Achieve or maintain eighty percent (80%) high or moderate Drivability Life for Interstates based on condition standards and treatments set for traffic volume categories.
- Achieve or maintain eighty percent (80%) high or moderate Drivability Life for the National Highway System, excluding Interstates, based on condition standards and treatments set for traffic volume categories.
- Achieve or maintain eighty percent (80%) high or moderate Drivability Life for the state highway system based on condition standards and treatments set for traffic volume categories.

(2) Bridges

MEASURES:

- Bridge deck area on the National Highway System in good condition
- Bridge deck area on the National Highway System in poor condition
- Bridge deck area on the state highway system in good condition
- Bridge deck area on the state highway system in poor condition
- Asset management program metrics related to bridge lead metrics, risk metrics, and freight movement metrics (See Appendix A for additional bridge metrics)

OBJECTIVES:

- Achieve or maintain the percent of National Highway System total bridge deck area in good condition at or above forty percent (40%).
- Achieve or maintain the percent of National Highway System total bridge deck area in poor condition below ten percent (10%).
- Achieve or maintain the percent of state highway system total bridge deck area in good condition at or above forty percent (40%).
- Achieve or maintain the percent of state highway system total bridge deck area in poor condition below ten percent (10%).
- Meet asset management program objectives related to bridge lead, risk and freight movement metrics (See Appendix A for additional bridge objectives).

(3) Maintenance

MEASURES:

- Overall Maintenance Levels of Service (MLOS) for the state highway system
- Level of Service (LOS) for snow and ice removal

OBJECTIVES:

- Achieve or maintain an overall MLOS B minus grade for the state highway system.
- Achieve or maintain a LOS B grade for snow and ice removal.

(4) Other Highway Assets

MEASURES:

- Asset management program metrics for other highway assets (See Appendix A for metrics for buildings, Intelligent Transportation Systems (ITS) equipment, fleet, culverts, geohazards, tunnels, traffic signals, walls, and rest areas)

OBJECTIVES:

- Meet or maintain asset management program objectives related to other highway assets (See Appendix A for buildings, ITS equipment, fleet, culverts, Geohazards, tunnels, traffic signals, walls, and rest areas objectives).

(5) Transit Assets: Small Urban & Rural Agency Assets

MEASURES:

- Rolling Stock: Percentage of revenue vehicles within an asset class that have either met or exceeded their useful life benchmark (ULB).
- Facilities: Percentage of facilities within an asset class rated below a 3.0 on the FTA TERM 5-point scale.

OBJECTIVES:

- Achieve or maintain performance of rolling stock and facilities to less than or equal to the percent performance calculated by the FTA for report year 2019. See Table 2 in Appendix B.

(6) Transit Assets: Bustang & Bustang Outrider Assets

MEASURES:

- Rolling Stock: Percentage of revenue vehicles within an asset class that have either met or exceeded their useful life benchmark (ULB).

OBJECTIVES:

- Achieve or maintain performance in each asset class that have either met or exceeded their ULB at no more than ten percent (10%).

c) MOBILITY:

The mobility goal area is intended to be achieved in the planning horizon from 2021 to 2030. A portion of the objectives within the goal area are aligned with the Greenhouse Gas Pollution Reduction Roadmap, detailing early action steps the state can take toward meeting near-term greenhouse pollution reduction targets, and HB19-1261 – *Climate Action Plan to Reduce Pollution,* statutorily required goals to reduce 2050 greenhouse gas pollution by ninety percent (90%) from 2005 levels. Some objectives within the goal area help increase reliability of the state highway system and increase the use of multimodal travel statewide.

(1) Reliability and Congestion

MEASURES:

- Operations Levels of Service (OLOS)
- Incident Clearance Time
- Vehicle Miles Traveled (VMT) and Vehicle Miles Traveled per Capita

OBJECTIVES:

- Achieve or maintain an Operations Levels of Service (OLOS) grade of C or better for eighty percent (80%) or greater of the state highway system.
- Achieve or maintain an annual average incident clearance time of twenty (20) minutes or less for highways covered by CDOT Safety Patrol and Heavy Tow vehicles.
- Manage congestion on our roads by reducing Vehicle Miles Traveled (VMT) and VMT per capita by ten percent (10%) on or before 2030, relative to current levels.

(2) Environmental Impact

MEASURES:

- Greenhouse gas (GHG) pollution from the transportation sector (in Carbon Dioxide Equivalents - CO_2e)
- Zero-emission vehicle (ZEV) registrations
- Percent and quantity of state transit fleet that are zero-emission vehicles
- Percent of state highway miles within a thirty-mile buffer of direct-current (DC) fast-charging stations
- Percent of Scenic and Historic Byways classified as electrified byways

OBJECTIVES:

- CDOT will work collaboratively with other state agencies and local partners to reduce statewide GHG pollution from the transportation sector by twenty-six percent (26%) by 2025, fifty percent (50%) by 2030, and ninety percent (90%) by 2050 relative to 2005 statewide GHG pollution levels.[1]
- Collaborate with other state agencies to increase electric vehicle registrations to support a future fleet of at least nine-hundred forty thousand (940,000) light-duty zero-emission vehicles by 2030.[2]
- Work with other state departments, transit agencies, and electric utilities to meet the transit vehicle goals specified the state's 2020 Electric Vehicle Plan to convert the state transit fleet to one-hundred percent (100%) zero-emission vehicles by 2050, with an interim target of at least one-thousand (1,000) zero-emission vehicles by 2030.[3]
- Collaborate with other state agencies, local governments, and private companies to increase the percentage of total state highway miles within a thirty-mile travel buffer of direct-current (DC) fast-charging stations from forty percent (40%) in fiscal year 2020 to one-hundred percent (100%) by 2030.[4]
- Coordinate with other state agencies, the Colorado Scenic & Historic Byways Commission, local governments, and individual site hosts to increase the number of Colorado Scenic & Historic Byways classified as electrified byways from three (3) currently to twenty-six (26) by the end of fiscal year 2025.[5]

OBJECTIVE NOTES:

1. CDOT will focus on the transportation greenhouse gas reduction elements of the Greenhouse Gas Pollution Reduction Roadmap, specifically vehicle electrification, VMT reduction, and the closer integration of greenhouse gas reduction measures and considerations in the planning, environmental, construction, and maintenance/operations elements of the project lifecycle. Other state agencies will simultaneously work to tackle issues related to the electricity generation, buildings, oil & gas, and agricultural sectors for a holistic statewide approach.
2. The Colorado Energy Office (CEO) will lead this effort in collaboration with CDOT, Colorado Department of Public Health and Environment (CDPHE), Colorado Department of Revenue (DOR), and other key stakeholder agencies while also coordinating with automakers, dealerships, utilities, nonprofit entities, and the general public to achieve this ambitious target by 2030. CDOT's role is to support and amplify this work, not to lead it.
3. CDOT is uniquely positioned to provide unified leadership in the transit electrification space given its statewide perspective and access to state, federal, and Volkswagen Settlement grant funding. CDOT will work to educate transit agencies on their options, support their fleet transition planning, and offset some of the incremental costs of going zero-emission. However, agencies themselves will play the central role in adopting new vehicle options when and where they make sense for their organizations and their riders.
4. CEO will lead this effort to ensure that sufficient public charging infrastructure is available through a combination of public and private investments. The State of Colorado does not intend to own or operate its own charging sites (beyond those at public facilities) but can provide grant support to ensure coverage in areas of the state that are not yet economically advantageous for private companies to serve. CDOT provides support for this effort through mapping, modeling, and data analysis that helps to identify prime locations while also funding limited infrastructure buildout along scenic byways, state parks, and other key areas of the rural charging network.
5. CDOT will play a coordinating role between the CEO, the Colorado Tourism Office, and the Scenic & Historic Byways Commission to educate individual byway groups on the benefits and opportunities associated with electric vehicle charging infrastructure while directing them to existing state grant and utility incentive programs to help facilitate this emerging market.

(3) Multimodal Options

MEASURES:

- Percentage of Coloradans commuting to work with multimodal options, including telecommuting
- Bustang bus service ridership

- Unlinked transit passenger trips for Colorado small urban and rural transit agencies

OBJECTIVES:

- Increase the percentage of Coloradans commuting to work using multimodal options, including those using telecommuting options, to thirty-five percent (35%) in 2030.
- Restore Bustang (I-25 and I-70 corridors) bus service ridership to pre-COVID-19 levels by the end of FY 2020-21 and grow it five percent (5%) per year thereafter. A pre-COVID-19 level is defined as June 2021 ridership being equivalent to June 2019 ridership, knowing that an equivalent annual number is not attainable while COVID-19 is currently affecting service. June 2019 ridership was 19,189 passengers for the month, with a FY 2018-19 total annual ridership of 238,000 riders.
- Increase unlinked passenger trips from small urban and rural transit agencies proportional to population growth levels from 2019 levels.

(4) Mobility Goal Area Considerations

- Staff will provide additional data for the mobility objectives when updates to PD 14.0 objectives are presented annually to the Transportation Commission. Examples include:
  - Operations Levels of Service (OLOS) grades in rural areas.
  - Operations Levels of Service (OLOS) grades in urban areas.
  - Operations Levels of Service (OLOS) grades for Colorado Freight Corridors.
- CDOT and the Transportation Commission will coordinate and collaborate with internal and external CDOT partners in efforts to achieve mobility goals in Colorado. Through this collaborative approach, CDOT will take actions to fulfill the goals outlined within the Administration's Greenhouse Gas Pollution Reduction Roadmap.
- VMT, GHG pollution levels, EV adoption, and multimodal options objectives will be aligned with the goals outlined in the Administration's Greenhouse Gas Pollution Reduction Roadmap and HB19-1261 (Climate Action Plan to Reduce Pollution).

VI. DOCUMENTS REFERENCED IN THIS POLICY DIRECTIVE

Appendix "A" CDOT Asset Management Metrics and Performance Targets

Appendix "B" CDOT Transit Asset Management

Appendix "C" Strategic Transportation Safety Plan (STSP) Tier 1 Strategies

Administration's Greenhouse Gas Pollution Reduction Roadmap

CDOT's Risk-Based Asset Management Plan

CDOT Transit Asset Management Group Plan

Colorado Strategic Transportation Safety Plan (STSP)

HB19-1261 (Climate Action Plan to Reduce Pollution)

Statewide Transportation Plan (2045)

VII. IMPLEMENTATION PLAN

The Division of Transportation Development, with the Division of Accounting and Finance, the Division of Maintenance and Operations, and the Office of Innovative Mobility, and in collaboration with other CDOT Divisions and CDOT Regions, will implement this Policy Directive. The Transportation Commission will direct funds to budget categories to support accomplishment of the objectives. The Division of Transportation Development will report annually on performance of the transportation system to track progress toward objectives, before the submission of the Department's annual budget. At a minimum, the Division of Transportation Development will review and update or reaffirm this Policy Directive with each Plan update cycle in collaboration with the Office of Policy and Government Relations, Division of Accounting and Finance, Division of Maintenance and Operations, Office of Innovative Mobility and other CDOT Divisions and CDOT Regions.

The Office of Policy and Government Relations shall post this Policy Directive on CDOT's intranet as well as on public announcements.

VIII. REVIEW DATE

This directive shall be reviewed on or before December 2022.

Herman F. Stockinger III

SECRETARY, TRANSPORTATION COMMISSION

11/19/2020

Date of Approval

Appendix "A"
CDOT Asset Management Metrics and Performance Targets

Asset	Objective	Objective Target	2019 Performance
Pavement	Achieve or maintain 80% high or moderate Drivability Life for Interstates based on condition standards and treatments set for traffic volume categories	80%	88.3%
	Achieve or maintain 80% high or moderate Drivability Life for the National Highway System, excluding Interstates, based on condition standards and treatments set for traffic volume categories	80%	84.0%
	Achieve or maintain 80% high or moderate Drivability Life for the state highway system based on condition standards and treatments set for traffic volume categories	80%	80.4%
Bridge Asset Condition	Achieve or maintain the percent of National Highway System total bridge deck area in good condition at or above 40%	40%	46.4%
	Achieve or maintain the percent of National Highway System total bridge deck area in poor condition below 10%	10%	6.1%
	Achieve or maintain the percent of state highway system total bridge deck area in good condition at or above 40%	40%	46.4%
	Achieve or maintain the percent of state highway system total bridge deck area in poor condition below 10%	10%	6.3%
Bridge Lead, Risk, and Freight Metrics	Percentage of expansion joints in fair, poor, or severe condition (by length) on CDOT-owned bridges	26% or less	37.6%
	Percentage of CDOT-owned bridge deck area that is unsealed or otherwise unprotected	35% or less	36.8%
	Percentage of CDOT-owned bridges over waterways that are scour critical	5.0%	6.2%
	Percentage of bridge crossings over Interstates, U.S. Routes and Colorado state highways with a vertical clearance less than the statutory maximum vehicle height of 14 feet-6 inches	1.0%	2.1%
	Percentage of bridge crossings over Interstates, U.S. Routes and Colorado state highways with a vertical clearance less than the minimum design requirement of 16 feet-6 inches	18.0%	20.3%
	Percentage of CDOT-owned bridges with a load restriction	0.9%	2.2%
	Percentage of CDOT-owned bridges posted for load	0.1%	0.4%
MLOS	Achieve or maintain an overall MLOS B minus grade for the state highway system	B-	B
	Achieve or maintain a LOS B grade for snow and ice removal	B	B
Buildings	Achieve or maintain an average statewide letter grade for CDOT-owned buildings at or above 85% C or better	85%	80%
ITS	Maintain or decrease the average percent useful life of ITS equipment at or below 90%	90%	82%
Fleet	Maintain or decrease the average percent useful life of CDOT fleet vehicles at or below 75%	75%	69%
Culverts	Maintain or decrease the percent of culverts in poor condition (have a culvert rating of 4 or less) at or below 5%	5%	5.2%
Geohazards	Achieve or maintain the percent of geohazard segments at or above risk grade B at or above 85%	85%	77%
Tunnels	Achieve or maintain the percent of network tunnel length with all elements in equal or better condition that 2.5 weighted condition index at or above 75%	75%	91%
Traffic Signals	Maintain or decrease the percent of signal infrastructure in severe condition at or below 2%	2%	7%
Walls	Maintain or decrease the percent of CDOT-owned walls, by square foot, in poor condition (have a rating of 4 or less) at or below 2.5%	2.5%	4.2%
Rest Areas	Achieve or maintain an average statewide letter grade for CDOT rest areas at or above 90% C or better	90%	61%

Appendix "B"
CDOT Transit Asset Management

The Federal Transit Administration's (FTA) October 1, 2016 Transit Asset Management (TAM) Rule established new asset management planning and reporting requirements for 49 U.S.C. Chapter 53 funding recipients and subrecipients that own, operate, or manage capital assets in the provision of public transportation. The TAM Rule requires transit providers to develop a TAM Plan to prioritize and guide investments in transit assets to keep the transit system in a State of Good Repair (SGR), and requires Departments of Transportation (DOTs) to sponsor a Group Plan for all Tier II transit providers (those without fixed-guideway and/or with less than 100 vehicles operating during peak service) who wish to participate. The Colorado DOT Transit Asset Management Group Plan (Group TAM Plan) was completed in the Fall of 2018 and covered a four-year planning horizon. The Group TAM Plan included a capital asset inventory of over $500 million and a prioritized project list of vehicle, equipment, and facilities projects of over $118 million through 2022.

The TAM Rule also outlined annual reporting and targeting requirements about the SGR of transit assets. It requires transit providers to report to FTA the number and type of active assets in each asset class every year. Once reporting is finalized, FTA calculates the percentage performance for the report year[1] and then CDOT, as the Group TAM Plan sponsor, sets realistic and achievable performance targets for each asset class for the next report year.

All active transit assets are required to be reported to FTA, regardless of the original funding source. There are 24 possible rolling stock asset class vehicle types, though the small urban and rural fleet currently includes just 11 of those vehicle types. It has been CDOT practice for nearly four years to prioritize pass-through funds to vehicle/project types that fall within six rolling stock asset classes, to vehicles with Americans with Disabilities Act (ADA) accessibility. In 2019, those vehicles made up around 93% of the rolling stock fleet, as emphasized in Table 1.

For the purposes of annual reporting, FTA defined equipment as non-revenue vehicles, narrowing down the types of reportable equipment to just two asset classes. Because of the practice of prioritizing pass-through funds towards ADA-compliant vehicles, CDOT has not awarded any pass-through funds for that type of equipment project in the last several years. As such, for PD 14.0 reporting purposes, Staff will focus rolling stock performance reporting on the six rolling stock asset classes—over-the-road-bus, bus, cutaway, minivan, aerial tramway, and van—and the two facilities asset classes, since those are the asset categories and classes that are impacted by CDOT's pass-through funds. Additional asset classes may be added in future PD-14 revisions if Staff believes that to be beneficial or necessary. Table 2 shows the performance measured by FTA in report year 2019[2], which Staff will use as baseline performance for annual reporting to the Transportation Commission.

[1] The FTA report year for CDOT and the small urban and rural agencies runs January 1 through December 31.
[2] State FY 2019-20

Appendix "B"
CDOT Transit Asset Management (Continued)

Table 1. Small Urban & Rural Transit Assets: Number of Assets per Asset Class, Report Year 2019		
Asset Category	**Asset Class**	**# of Assets**
Rolling Stock	AB – Articulated Bus	1
	AO – Automobile	48
	BR – Over-the-road Bus	**41**
	BU – Bus	**444**
	CU – Cutaway	**317**
	MV – Minivan	**142**
	OR – Other	24
	SB – School Bus	1
	SV – Sports Utility Vehicle	10
	TR – Aerial Tramway	**68**
	VN – Van	**144**
Equipment	Automobiles	43
	Trucks and Other Rubber Tire Vehicles	41
Facilities	Passenger/Parking Facilities	43
	Administrative/Maintenance Facilities	46

Table 2. Small Urban & Rural Transit Assets: Percent of Asset Class Beyond SGR, Report Year 2019		
Asset Category	**Asset Class**	**Performance (%)**
Rolling Stock	BR – Over-the-road Bus	17.95%
	BU – Bus	24.81%
	CU – Cutaway	24.61%
	MV – Minivan	23.85%
	TR – Aerial Tramway	83.82%
	VN – Van	13.79%
Facilities	Passenger/Parking Facilities	2.78%
	Administrative/Maintenance Facilities	8.89%

Appendix "C"
Strategic Transportation Safety Plan (STSP) Tier 1 Strategies

A. Name a Safety Champion to Lead a Proactive Safety Program

Name a safety champion to lead an inclusive safety program with the responsibility, resources, and authority to advance safety strategies and monitor effectiveness. This strategy will provide a focused approach to championing, coordinating, and implementing safety programming. *CDOT will lead implementation with support from Colorado State Patrol (CSP), Colorado Department of Public Health & Environment (CDPHE), and Colorado Department of Revenue (CDOR).*

B. Build a Safety Advocacy Coalition

Build a safety coalition of advocacy groups and state and local agencies to function as a lobbying and advocacy group. This group will work toward revisions to laws and policies at all phases of development and enforcement. This strategy will increase the visibility of key safety issues in policy discussions and create a central forum for strengthening relationships among participants and decision-makers in safety initiatives. *CDOT will lead implementation with support from CSP and CDPHE.*

C. Institutionalize Safety Roles and Responsibilities

Establish agreements that define the ways agencies and organizations work together to deliver safety programs, including roles and responsibilities. These will be formal mechanisms such as a memorandum of understanding. Less formal arrangements may be appropriate at local levels. *CSP and CDOT will lead implementation with support from CDPHE and CDOR.*

D. Coordinate with Existing Safety Programs

Coordinate the development and implementation of safety programs, incorporating strategies among agencies at the state and local level (example existing programs include CDOT's Whole System, Whole Safety Program, and regional and local Vision Zero programs). This strategy will improve the reach and impact of the state's safety programs and avoid duplication of safety program development efforts. *CDOT will lead implementation with support from CSP.*

E. Promote Consistent Safety Messaging

Coordinate the efforts of safety agencies and advocacy groups to develop consistent public-facing safety messaging to be distributed to audiences across the state. This strategy will create greater public safety awareness through consistent messaging. *CDOT Highway Safety Office and CDOT Office of Communications will lead implementation with support from CSP, CDPHE, and CDOR.*

F. Develop Education Campaigns for High-Risk Behaviors

Develop outreach campaigns aimed at high-risk groups, such as aggressive, distracted, and impaired drivers, with the goal to enhance and coordinate efforts among statewide education platforms. Occupant protection education campaigns will also be included within this strategy. *CDOT Highway Safety Office and CDOT Office of Communications will lead implementation with support from CSP, CDPHE, and CDOR.*

G. Provide Transportation Safety Education to Students and Families

Establish a culture of safety among young people by expanding existing and developing new transportation safety education programs that engage them over many years. One aim of this strategy is to develop a comprehensive curriculum that can be used for education statewide, including education on how to be a safe pedestrian and bicyclist. *CSP and CDOT will lead implementation with support from CDPHE.*

H. Prioritize Transportation Safety Funding

Increase the importance of safe infrastructure and transportation in transportation funding decisions. Educate funding decision-makers on the importance of safety and how funds could be used to make improvements. *Colorado Transportation Commission will lead implementation with support from CDOT, CSP, CDPHE, and CDOR.*

Appendix "C"
Strategic Transportation Safety Plan (STSP) Tier 1 Strategies (Continued)

I. Prioritize Safety in Transportation Planning, Facility Design, and Project Selection
Review policies and processes of roadway planning, design, and project selection to determine what role safety plays in decision-making. This includes updating existing planning and design guidelines and standards to integrate enhanced safety measures. *CDOT and CSP will lead implementation with support from CDPHE.*

J. Educate Decision-Makers on the Effectiveness of Occupant Protection Laws
Research and document the benefits of occupant protection laws, such as seatbelt use, helmet use, and restrictions on personal device use. Using available data, this strategy aims to educate legislators, commissioners, and other decision-makers on the benefits of such laws to aid in the development of new policies. *CDOT will lead implementation with support from CDPHE, CSP, and CDOR.*

K. Increase Requirements for New and Renewal Driver Licensing
Expand the graduated driver licensing (GDL) system to increase education and practice requirements for new drivers to obtain a license, and develop appropriate testing requirements to verify driver competency with increased age. *CDOR will lead implementation with support from CSP and CDPHE.*

L. Establish a Framework for Streamlining Data Management
Improve data gathering, reporting, storage, linkage, processing, analyses, and dissemination throughout the state for traffic records databases following the FHWA measures of quality: timeliness, accuracy, completeness, uniformity, integration, and accessibility. The databases will provide more uniform confidence in crash mitigation for agencies at both the state and local level. *CDOT will lead the implementation with support from Statewide Traffic Records Advisory Committee (STRAC), CSP, and CDPHE, as directed by the newly formed leadership group that will be a liaison between the Executive Directors of the partner agencies and STRAC.*

M. Prioritize and Promote Proven Safety Toolbox Strategies
Educate state and local traffic engineers on existing, known, and, effective safety toolbox strategies in transportation facility design, construction, and operation. This strategy will promote inclusion of proven strategies in design practices and development of Local Road Safety Plans by local agencies. C*DOT will lead implementation with support from CSP.*

N. Implement Systemic Infrastructure Safety Improvement Strategies
Build on existing safety implementation projects and programs. Identify and implement the most effective wide-scale systemic safety mitigation strategies in conjunction with implementing hot-spot improvement projects. Examples of these strategies include, but are not limited to, rumble strips, median barriers, and fully protected left-turn phasing. *CDOT will lead implementation with support from local city and county transportation departments as well as CDOT Region Traffic Engineers.*

O. Increase Education On and Implementation of Data-Driven and Automated Enforcement
Increase implementation of data-driven enforcement for speeding and red-light running at high-crash locations. Educate decision- makers on the effectiveness of automated enforcement as a safety enhancement rather than as a revenue generator. *CDOT will lead implementation with support CSP.*

Resolution #TC-2020-11-11

Adoption of updated Policy Directive 14.0 "Policy Guiding Statewide Plan Goals & Objectives".

Approved by the Transportation Commission on November 19, 2020.

WHEREAS, the Colorado Transportation Commission (the Commission has statutory authority pursuant to § 43-1-106(8)(a) C.R.S. to formulate policy concerning transportation systems in compliance with 23 U.S.C. § 134, 135, and 450; PL 114-94 ("Fixing America's Surface Transportation Act" or "FAST Act")) and its regulations; and to undertake transportation planning under § 43-1-1103 C.R.S; and

WHEREAS, a statewide plan is part of the state and federally required statewide transportation planning process; and

WHEREAS, Policy Directive 14.0 states that the policy will be brought forward for consideration by the Commission as goal areas, objectives, and metrics are revised; and

WHEREAS, the Commission annually reviews Policy Directive 14.0 to determine if there is a need to modify goal areas, performance metrics, or objectives; and

WHEREAS, Policy Directive 14.0 has been revised to include the new goal areas of safety, asset management, and mobility; to revise the language of the goals; to update definitions within the Policy Directive; to revise, change, and add new performance objectives and metrics in each goal area; to reflect direction from CDOT executive management, the Transportation Commission, and the Governor of Colorado; and to align with performance objectives in the Colorado Strategic Transportation Safety Plan (STSP), the multi-agency Greenhouse Gas Pollution Reduction Roadmap, and the CDOT Transit Asset Management Group Plan, among other efforts; and

WHEREAS, over the past several months, the Commission reviewed and concurred with the proposed changes to Policy Directive 14.0; and

WHEREAS, Policy Directive 14.0 does not limit the Commission's flexibility to make funding decisions and to consider new and different information not contemplated in this Directive.

NOW THEREFORE BE IT RESOLVED, that the Commission adopts the updated Policy Directive 14.0 "Policy Guiding Statewide Plan Goals & Objectives" as reflected in Attachment A to this resolution.

Herman F. Stockinger III

Herman Stockinger, Secretary
Transportation Commission of Colorado

11/19/2020
Date

COLORADO
Department of Transportation
Office of the Chief Engineer

TO: CDOT Personnel

FROM: Stephen Harelson, Chief Engineer

CC:

- William Johnson, Performance and Asset management Branch Manager
- Toby Manthey, Asset Management Program Manager
- Britton Stocks, Asset Management Analyst
- CDOT Headquarters Asset Managers

DATE: May 12, 2022

RE: Processes to Change Treatments on Approved Asset-Management Treatment Lists

Purpose:

CDOT's Transportation Asset Management (TAM) program requires 11 of the Department's 12 asset classes[1] to submit an annual list of treatments.[2] Treatments are typically submitted four years in advance of the intended project-delivery year. This is intended to provide sufficient time for project planning and delivery. However, due to the extended time between creation of the lists and delivery of the treatments, there often are substantial changes to treatments, including the addition or removal of entire treatments. The purpose of this memo is to document change processes for each asset class, including roles and responsibilities. This will help ensure that changes to the treatment list are consistent with CDOT's performance goals, are approved by the relevant authority, and are properly documented.

Background:

The Colorado Transportation Commission (TC) adopted "*Policy Directive (PD) 1609.0: Transportation Asset Management"* in January 2021. The directive laid out in broad terms the policies and procedures of the TAM program. To expand upon that effort, the TAM program is drafting *procedural* directive 1609.1. This memo will serve as an appendix to the procedural directive.

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[1] *The Maintenance Levels of Service (MLOS) asset class does not submit an annual treatment list.*

[2] *Treatments form the basis of construction projects. A single treatment may be delivered as a standalone project or may be bundled with other treatments to make a larger project.*

PD 1609.0 established that a primary function of the TAM program is to develop "planning budgets" for each of the asset classes four years in advance. The program also develops annual lists of treatments for all asset classes (excluding Maintenance Levels of Service, or MLOS). Like the planning budgets, these lists are typically developed and approved four years in advance of project delivery to facilitate planning.

Historically, treatment lists have been approved as a snapshot of treatments at a particular moment in time (four years in advance). The lists are approved by two of the following: the Executive Director (or designee), the Chief Engineer and the Chief Financial Officer.

However, the lists should ultimately exist as "living documents" that are updated as changes are made to treatments. The TAM program is therefore establishing specific processes for each asset class to approve changes. These processes are tailored to each class and create an approving authority who accepts or rejects proposed changes, ensuring that updates align with performance goals. This general process was presented to and agreed upon by the Regional Transportation Directors in mid-2020 and was discussed in the TAM Oversight Committee in 2021 and 2022.

In addition to the treatment-change processes outlined below, each asset class maintains an appeals process. If a change request is denied by the approving authority/designee (typically the headquarters asset manager), Regional Transportation Directors can submit an appeal form to the Chief Engineer for final determination. The exception to this is the Fleet asset class, for which appeals are routed to the Director of Maintenance and Operations.

Details:

Documented below are the change processes for asset management treatment lists, by asset class:

1. **Pavement:**
    - **Approval process:** Submission of official form[3] to approving authority or designee(s). Supporting documentation, such as Pavement Justification Reports and pictures of pavement cores, may be submitted directly to the Approving Authority on the date that the official form is submitted. The Approving Authority has 30 days to complete the review from the "Date Change Requested" on the official form.
    - **Approving Authority:** Materials and Geotechnical Services Manager — Craig Wieden
    - **Approving Designee:** Pavement Management Services Manager — Laura Conroy

3 The approving authority listed in this section will supply the official form.

- **What changes are applicable:** Adding treatments not on the original treatment list.[4] Removing a treatment from the original treatment list that was a model match.[5] Changing to a more substantial level of pavement treatment from the original treatment list. Changes to treatment limits that cause a treatment to no longer satisfy the model-match criteria. Increases in pre-advertisement planned-treatment budget that exceed planned-treatment unit cost estimate by more than 50 percent without an increase in length, and/or results in the treatment length being reduced by 33 percent or more.
- **Changes not Requiring Approval:** Moving approved treatments to a different list year. Performing a lesser level of treatment than the approved treatment. Increasing the length of a treatment without increasing the budget. Delivering a treatment at a decreased planned treatment budget.
- **Frequency of approval:** As they arise.
- **Publication of Changes:** Annual update to four-year TAM treatment list.

2. **Bridge:**
    - **Approval process:** Asset manager or unit leader makes updates to Bridge Structure Asset Management (SAM) plan.
    - **Approving Authority:** HQ Asset Manager—Natasha Butler.
    - **Approving Designee:** HQ Asset Manager — Jessica Martinez, Region 1 Unit Leader — Tristan Siegel, Region 2 Unit Leader — Joel Johnson, Region 3 Unit Leader — Sam Abraham, Region 4 Unit Leader — Ali Harajli, Region 5 Unit Leader — Trever Wang.
    - **What changes are applicable:** Change to treatment type or treatment budget, addition of an entirely new treatment, or removal of a treatment from approved TAM treatment list.
    - **Frequency of approval:** As changes arise.
    - **Publication of Changes:** Treatment changes included in snapshot of updated Bridge SAM Plan every six months, and in annual update to four-year TAM treatment list.

3. **Culverts:**
    - **Approval process:** Asset manager or unit leader makes updates to Culverts Structure Asset Management (SAM) Plan.
    - **Approving Authority:** HQ Asset Manager—Natasha Butler.
    - **Approving Designee:** HQ Asset Manager — Jessica Martinez, Region 1 Unit Leader — Tristan Siegel, Region 2 Unit Leader — Joel Johnson, Region 3 Unit

[4] *The original list is the list submitted to the TAM program by the headquarters asset manager, and then approved by CDOT executives (i.e., two of the following: Chief Engineer, Chief Financial Officer, Executive Director or designee).*

[5] *As defined by Pavement Management criteria.*

Leader — Sam Abraham, Region 4 Unit Leader — Ali Harajli, Region 5 Unit Leader — Trever Wang.
- **What changes are applicable:** Change to treatment type or treatment budget, addition of an entirely new treatment, or removal of a treatment from approved TAM treatment list.
- **Frequency of approval:** As changes arise.
- **Publication of Changes:** Annual update to four-year TAM treatment list.

4. **Walls:**
    - **Approval process:** Asset manager or unit leader makes updates to Walls Structure Asset Management (SAM) Plan.
    - **Approving Authority:** HQ Asset Manager—Natasha Butler
    - **Approving Designee:** HQ Asset Manager — Jessica Martinez, Region 1 Unit Leader — Tristan Siegel, Region 2 Unit Leader — Joel Johnson, Region 3 Unit Leader — Sam Abraham, Region 4 Unit Leader — Ali Harajli, Region 5 Unit Leader — Trever Wang.
    - **What changes are applicable:** Change to treatment type or treatment budget, addition of an entirely new treatment, or removal of a treatment from approved TAM treatment list.
    - **Frequency of approval:** As changes arise
    - **Publication of Changes:** Annual update to four-year TAM treatment list.

5. **Buildings:**
    - **Approval process:** Submission of official change-request form to the approving authority or designee.[6]
    - **Approving Authority:** Marcella Broussard and John Lorme.
    - **Approving Designees:** Asset Managers — Hope Wright or David Fox
    - **What changes are applicable:** Deleting/adding a treatment from the treatment list or shifting a treatment from one fiscal year to another.
    - **Frequency of approval:** As they arise.
    - **Publication of Changes:** Annual update to four-year TAM treatment list.

6. **Rest Areas:**
    - **Approval process:** Submission of official change-request form to the approving authority or designee.[7]
    - **Approving Authority:** Marcella Broussard and John Lorme.

6 *The approving designees listed in this section will supply the official form.*

7 *The approving designees listed in this section will supply the official form.*

- **Approving Designees:** Asset Managers — Hope Wright or David Fox
- **What changes are applicable:** Deleting/adding a treatment from the treatment list or shifting a treatment from one fiscal year to another.
- **Frequency of approval:** As they arise.
- **Publication of Changes:** Annual update to four-year TAM treatment list.

7. **Tunnels:**
   - **Approval process:** Submission of official change-request form[8] to the approving authority or designee.
   - **Approving Authority (for treatment modifications):** Asset Manager — Tyler Weldon
   - **Approving Designees (approving authority for treatment additions or subtraction of entire treatment and designee for treatment modifications):** Chief Engineer — Steve Harelson
   - **What changes are applicable:** Addition or subtraction of the entire treatment. Changes in budget, scheduled year, and scope of the treatment.
   - **Frequency of approvals:**
     i. Treatments on the tunnels list can be added and subtracted upon approval by the Chief Engineer, annually and biannually, at a date to be designated by the tunnels asset manager. Requests for emergency additions can be made to the Chief Engineer at any time.
     ii. Requests to change treatment budgets can be made at any time.
     iii. Requests to delay and advance a treatment year can be made at any time.
   - **Publication of Changes:** Annual update to four-year treatment list.

8. **Fleet:**
   - **Approval process:** Submission of official change-request[9] form to the approving authority or designee. The request form is submitted to the Fleet Manager, who routes the form to the Director of Maintenance and Operations for approval.
   - **Approving Authority (except for "in lieu of" changes):** DMO Director — John Lorme. The DMO Director approves the changes and an annual updated replacement plan.
   - **Approving Authority for "in lieu of"[10] changes:** Asset Manager — Howard Ray or Heavy Fleet Administrator — Robert Brogdon.

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8 *The "approving authority for treatment modifications" listed in this section will supply the official form.*

9 *The HQ fleet asset manager listed in this section will supply the official form.*

10 An "in lieu of" change is when a different vehicle than was in the replacement plan is replaced. The replaced vehicle must be the same class-code as the vehicle originally targeted for replacement in the plan.

- **What changes are applicable:** Any changes to equipment-class code, out-of-cycle replacements, and "in lieu of" changes.
- **Frequency of approvals:** Annually before the updated replacement plan is approved by the Director of Maintenance and Operations.[11]
- **Publication of Changes:** Annual update to four-year TAM treatment list.

9. **Signals:**
   - **Approval process:** Submission of official change-request form[12] to the approving authority or designee.
   - **Approving Authority:** Asset Manager — Nitin Deshpande
   - **Approving Designees:** Professional Engineer II — Benjamin Acimovic
   - **What changes are applicable:** Addition or subtraction of entire treatments. Significant[13] changes in budget, scheduled year, and scope of the treatment.
   - **Frequency of approval:** As they arise.
   - **Publication of Changes:** Annual update to four-year TAM treatment list.

10. **ITS:**
   - **Approval process:** Submission of official change-request form[14] to the approving authority or designee.
   - **Approving Authority:** ITS Branch Manager and Superintendent — Bob Fifer
     Approving Designees: Asset Manager — Allie Axley or Administrator III — Tammy Feltis
   - **What changes are applicable:** Changes of more than $10,000 to a single replacement.
   - **Frequency of Approval:** As they arise.
   - **Publication of Changes:** Annual update to four-year TAM treatment list.

11. **Geohazards:**
   - **Approval process:** Submission of official change-request form[15] to the approving authority or designee.
   - **Approving Authority:** Geohazards Asset Manager — Robert Group
   - **Approving Designee:** Senior Engineering Geologist — Nicole Oester

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11 In lieu of changes can be made throughout the year. Other changes must be made annually before replacement plan approval by the Director of DMO.

12 *The approving authority listed in this section will supply the official form.*

13 As defined by the asset manager.

14 The approving designee listed in this section will supply the official form.

15 The approving authority listed in this section will supply the official form.

- **What changes are applicable:** Changes to treatment locations, treatment types, or addition of treatment elements from other asset classes.
- **Frequency of approval/request:** Treatment list changes may be proposed at any time if they are related to a change in the deterioration rate of a geohazard asset. Any other changes should be proposed and approved at least six months before the fiscal year in which the treatment will be delivered to accommodate potential funding transfers between Regions.
- **Documentation Process:** Official form and column in the treatment list marking the change.
- **Publication of Changes:** Annual update to four-year TAM treatment list.