COLORADO
Department of Transportation

Risk-Based Asset Management Plan

Version 2

June 30, 2019

COLORADO
Department of Transportation

CDOT Risk-Based Asset Management Plan Submission

I, Shoshana M. Lew, Executive Director of the Department of Transportation, State of Colorado, do hereby submit CDOT's *Risk-Based Asset Management Plan* of 2019, which is designed to satisfy requirements of 23 U.S.C. 119(e) and 23 CFR Part 515.

Shoshana M. Lew

Executive Director, Colorado Department of Transportation

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Date

Risk-Based Asset Management Plan

Colorado Department of Transportation

Prepared by the Department with the assistance of

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Letter from the Executive Director

Dear Federal Highway Administration Review Team,

Shoshana M. Lew
CDOT Executive Director

I am pleased to present the Colorado Department of Transportation's (CDOT) *Risk-Based Asset Management Plan* of 2019, which satisfies requirements in 23 CFR 515.9 for asset management plans for state Departments of Transportation (DOTs).

Employed deliberately, asset management can help planners and decision makers look across a portfolio, consider a range of investments and determine how best to minimize risk and disruption while maximizing benefits for the economy, individual communities and the traveling public.

CDOT's plan helps the Department achieve these objectives. The plan features elements including:

- A summary of National Highway System (NHS) bridge and pavement assets and condition in Colorado, regardless of ownership.
- Asset management objectives that align with CDOT's mission.
- A risk-mitigation plan.
- Identification of performance gaps.
- A life-cycle plan for pavement and bridges.
- Investment strategies.
- A financial plan for pavement and bridge assets.

Colorado has experienced explosive growth in the early 21st century, with population soaring 40 percent in the past 20 years. Growth means more travel, and more travel means increased cost to maintain the state highway system.

That is where the Risk-Based Asset Management Plan comes in. In these pages, you will learn how CDOT is stretching its dollars through asset management. You will see how we use cost-benefit analysis and software systems to inform our asset budgets, as well to recommend roadway maintenance treatments, rehabilitations and replacements. You will see how we manage environmental, social and economic threats. And you'll see our long-term funding and cost forecasts.

While this plan focuses on bridges and pavements, including all NHS assets in the state, CDOT operates a robust asset management program that includes a dozen asset classes. These programs are managed with just as equal rigor as the pavement and bridge programs.

CDOT in 2013 was one of the very first state DOTs to produce an asset management plan. This new plan demonstrates that the Department's commitment to asset management remains just as strong as we continue to help Colorado be more productive, more innovative and more connected than ever before.

Regards,
Shoshana M. Lew
CDOT Executive Director

1.0 Introduction

1.1 Colorado's Commitment to Asset Management

Colorado's transportation infrastructure is as diverse as the state. 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.

These assets enable the Colorado Department of Transportation (CDOT) to fulfill its mission: *To provide the best multimodal transportation system that effectively and safely moves people, goods, and information.* CDOT is therefore committed to managing this infrastructure to the highest standards possible, for as long as possible. Risk-based asset management is at the core of this commitment.

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."[1]

CDOT's Mission
To provide the best multimodal transportation system that effectively and safely moves people, goods, and information.

Facing increasingly constrained financial resources, CDOT sees effective management of transportation assets as a priority, as do federal transportation officials. In 2012, the federal Moving Ahead for Progress in the 21st Century Act (MAP-21) codified asset management principles into law, requiring all states to develop risk-based transportation asset management plans (TAMPs). The 2015 Fixing America's Surface Transportation (FAST) Act reaffirmed this requirement, and the Federal Highway Administration (FHWA) released its final rules on transportation asset management plans on Oct. 24, 2016.[2]

Managing assets effectively enables 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. The top priority of the traveling public is to maintain and improve the condition of roads and bridges, according to a CDOT phone survey. In fact, bridge and pavement assets are the focus of this asset management plan and the biggest recipients of the Department's funding. Properly designed and maintained roadways make travel in a variety of modes easy for residents, visitors, and businesses.

This plan will play a critical role in defining CDOT's path forward. 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 the public.

1 *American Association of State Highway and Transportation Officials' Subcommittee on Asset Management.*
2 *This rule can be found at 23 Code of Federal Regulations (CFR) Part 515—Asset Management Plans, and 23 CFR Part 667—Periodic Evaluation of Facilities Repeatedly Requiring Repair and Reconstruction Due to Emergency Events.*

1.2 Plan Overview

This plan satisfies all federal requirements for a "complete" asset management plan, including addressing Colorado's NHS pavement and bridges, regardless of ownership. The document is organized based on FHWA guidance and includes:

- **Introduction.** The following pages of this introduction (Section 1) feature CDOT's vision for the plan and describe the structure and history of the Department's asset management program. The introduction also lists asset-management objectives and targets for National Highway System (NHS) pavement and bridge assets. In addition, the section describes the asset-management planning process as it relates to the Statewide Transportation Improvement Program (STIP).
- **Risk Management.** Section 2 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. This section also describes recent changes to CDOT's risk register and how the Department incorporates risk analysis to help optimize asset investment decisions.
- **Inventory and Condition.** Section 3 provides a summary of inventory and condition data for CDOT's pavement and bridge assets, as well as for pavement and bridges on the NHS in Colorado, regardless of ownership.
- **Performance Targets and Gaps**. Section 4 presents both federal- and state-established performance measures and CDOT's targets for the entire state highway system and for NHS pavement and bridges. The section also describes gaps between current and target performance.
- **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.
- **Financial Planning.** Section 6 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 7 identifies investment strategies for CDOT's asset management program. The strategies include estimated spending by work type.
- **Next Steps.** Section 8 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. Other improvements include preparing CDOT's workforce for the future, increasing cross-asset collaboration, using data more effectively, and increasing the consideration of risk and resilience in the asset management process.

1.2.1 Changes from 2018's Certified Initial Plan

CDOT has made the following changes to plans outlined in its 2018 *Initial Transportation Asset Management Plan*, which was certified by FHWA:

- The Department expressed plans to include all its asset programs (which now total 12) in this plan. The Department instead has chosen to focus this plan on the required asset classes of pavement and bridges. CDOT will reevaluate the assets included in its asset management plan on an ongoing basis.

- Certain processes that were in draft stage have evolved since the 2018 plan. For example, processes described in Section 2 for considering risk in making asset-management investments are more mature in this plan, albeit still in development.

- Rather than developing 10-year targets for National Performance Measures, as anticipated at the time of the Initial TAMP, CDOT has included targets for 2030 based on its internal metrics for asset condition.

- Investment strategies are now represented by funding levels based on five work types. The broad strategies that represented investment strategies in the *Initial TAMP* have been moved to the Life-Cycle Planning section of this document.

1.3 Vision Statement, Objectives and Targets

1.3.1 Vision Statement

The vision of CDOT's *Risk-Based Asset Management Plan* is to advance processes that optimize asset investments to achieve Department performance goals. The plan prepares 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.
- 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.
- Satisfying federal requirements for asset management plans.

1.3.2 Objectives

CDOT's Policy Directive 14 (PD-14) contains objectives and performance targets that guide the distribution of financial resources. Objectives in the directive align with MAP-21 National Performance Areas, such as infrastructure condition. The Department's infrastructure objective, including for pavement and bridges, is "to preserve the transportation infrastructure condition to ensure safety and mobility at a least life-cycle cost." This

objective is consistent with the purpose of asset management, which is to "achieve and sustain a state of good repair over the life cycle of the assets at a minimum practicable cost."

1.3.3 Performance Targets

CDOT has established the following targets for National Performance Measures for National Highway System (NHS) pavement and bridges:

Asset Management Performance Targets—Pavement

- Increase the percentage of Interstate pavement in Colorado in Good condition to 46 percent in 2020, from 44 percent in 2018. Increase the percentage of such pavement in Good condition to 47 percent in 2022.
- Ensure that no more than 1 percent of Interstate pavement in Colorado is in Poor condition in 2020, down from 2.5 percent in 2018. Maintain the percentage of such pavement in Poor condition at no more than 1 percent in 2022.
- Increase the percentage of non-Interstate National Highway System (NHS) pavement in Colorado in Good condition to 50 percent in 2020, from 42 percent in 2018. Increase the percentage of such pavement in Good condition to 51 percent in 2022.
- Ensure that no more than 1 percent of non-Interstate National Highway System (NHS) pavement in Colorado is in Poor condition in 2020, compared to 3 percent in 2018. Ensure no more than 2 percent of such pavement is in Poor condition in 2022.

Asset Management Performance Targets—Bridges

- Ensure that no less than 45 percent of bridge deck area on the National Highway System in Colorado is in Good condition in 2020, compared to 47 percent in 2018. Ensure that no less than 44 percent of bridge deck area on the National Highway System is in Good condition in 2022.
- Ensure the percentage of bridge deck area on the National Highway System in Colorado in Poor condition in 2020 does not exceed 2018's performance of 4 percent. Maintain the percentage of poor bridge deck area at no more than 4 percent in 2022.

These targets, current performance, and associated gap analyses are featured in Sections 4 of this report along with internal metrics and targets that CDOT uses to evaluate asset performance.

1.4 Asset Management at CDOT

CDOT has long embraced asset management as standard business practice. Since 2011, CDOT has guided investment decisions by developing budget scenarios and exploring the relationship between funding and performance. In 2013, the Department began holding an annual budget-setting workshop at which Department experts make data-driven funding tradeoffs among asset types to develop a recommendation for spending asset-management funds.

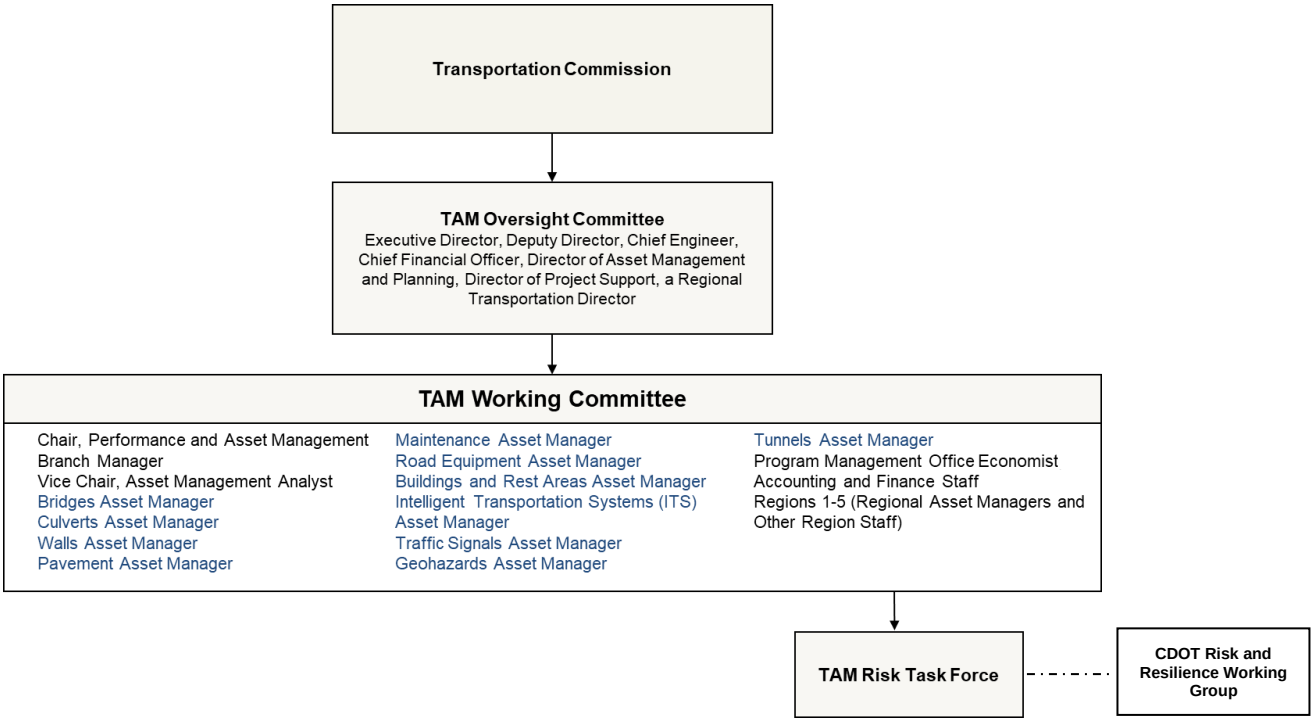
The Department published its first asset management plan with the *Risk-Based Asset Management Plan* of 2013. Since then, the Department has continued to implement and refine asset management processes. Early in 2018, CDOT developed the *Initial Transportation Asset Management Plan* for pavements and bridges on the National

Highway System (NHS). That work established the foundation for this *Risk-Based Asset Management Plan (Volume 2) of 2019*.

1.4.1 Program Structure

CDOT staff has worked in recent years with the Colorado Transportation Commission to develop a governance structure for the Department's asset management program. The governance structure includes a Transportation Asset Management (TAM) Oversight Committee and a TAM Working Committee. *(See Figure 1 below.)*

Figure 1: CDOT Asset Management, Organizational Structure



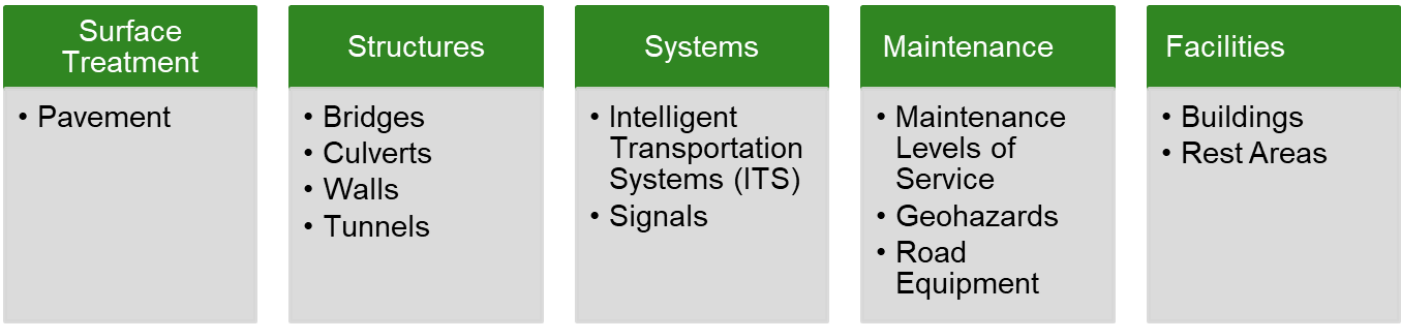
The Transportation Commission sets the strategic direction for the asset-management program by approving performance metrics, targets, and annual planning budgets for all asset programs. Meanwhile, the TAM Oversight Committee includes the Department's Executive Director, Deputy Director, Chief Engineer, Chief Financial Officer, Director of Asset Management and Planning, Director of Project Support and a Regional Transportation Director.

The Oversight Committee advises the Department on the size of the overall annual asset management budget, what assets should be included in the asset-management program, and other issues. The Transportation Commission typically reviews these recommendations and approves, modifies or rejects them.

The TAM Working Committee assists CDOT in ways including developing new processes and prioritized project lists and by communicating policies, procedures and deadlines to asset managers, the Regions and other work units.

The TAM Risk Force advances risk and resiliency practices within the asset management program. The Task Force includes CDOT's Resilience Program Coordinator, who helps ensure Task Force plans align with those of CDOT's Risk and Resilience Working Group.

Figure 2: CDOT Asset Categories and Classes



CDOT's asset management program is organized into five asset categories, represented in the green boxes above. Each category contains one or more asset classes, shown in the gray boxes above.

As of summer 2019, CDOT's asset management program includes 12 asset classes, each of which has its own inventory, performance metrics, targets, and project selection and prioritization processes. Although this plan focuses on NHS bridges and pavement to fulfill federal requirements, CDOT manages the 12 asset classes with similar rigor. CDOT looks at the 12 asset classes as falling under five broad categories shown in Figure 2 above: Surface Treatment, Structures, Systems, Maintenance and Facilities.

The Surface Treatment category includes CDOT's pavement program. The Structures category includes CDOT's bridges, culverts, walls and tunnels programs. The Systems category includes the Intelligent Transportation Systems and signals programs. The Maintenance category includes CDOT's Maintenance Levels of Service, geohazards and road equipment programs. The Facilities category includes CDOT's buildings and rest areas programs.

1.4.2 Asset Management Systems

CDOT's asset management program has developed and operates asset management systems for pavement and bridges that meet minimum standards under 23 CFR 515.17, including:

- *Collecting, processing, storing, and updating inventory and condition data for all NHS pavement and bridge assets.*
- *Forecasting deterioration for all NHS pavement and bridge assets.*
- *Determining the benefit-cost over the life cycle of assets to evaluate alternative actions (including no action decisions), for managing the condition of NHS pavement and bridge assets.*
- *Identifying short- and long-term budget needs for managing the condition of all NHS pavement and bridge assets.*

- *Determining the strategies for identifying potential NHS pavement and bridge projects that maximize overall program benefits within the financial constraints.*

- *Recommending programs and implementation schedules to manage the condition of NHS pavement and bridge assets within policy and budget constraints.*

The Department has operated such asset management systems for pavement since the late 1990s and for bridges since 2013. These asset management systems, including the Department's Asset Investment Management System, have historically focused on the CDOT-owned network, which includes the vast majority of NHS pavement and bridges. The Department has developed preliminary models to forecast pavement and bridges for the entire NHS, regardless of ownership, and is refining deterioration rates and other inputs.

1.5 Transportation Planning

1.5.1 Statewide Transportation Improvement Program (STIP)

FHWA in its rulemaking has clarified that the asset management process is distinct from the state transportation investment plan process that states use to identify the projects to which they may apply their federal formula dollars. Nevertheless, the rule does call for "state DOTs to integrate asset management plans into the transportation planning processes that lead to their [State Transportation Improvement Plans]." CDOT believes that these two processes can and should be complementary, and is therefore taking a holistic look at developing a strategic 10-year pipeline of projects that includes both capital and asset management needs.

Processes described in this asset management plan—including investment strategies and processes to establish planning budgets for CDOT's asset programs—currently lead toward development of a rolling, four-year program of asset management projects, or project list. This program represents the projects that CDOT intends to deliver for asset management. An update to the list is developed every year and communicated throughout the Department and to CDOT's planning partners.

The four-year program of projects forms a major component of projects that will go into CDOT's Statewide Transportation Improvement Program (STIP). Projects in the STIP can include asset management treatments that have been bundled with other projects, or standalone projects.

Federal regulations require CDOT to develop a STIP, which is a four-year planning document for state transportation projects. CDOT updates this plan annually. Projects included in the annual plan come from the 20-year statewide transportation plan. The Transportation Commission takes various factors into account when prioritizing projects, such as funding interplay, highway safety issues, regional priorities, and the balance of long- and short-term benefits of specific projects.

While CDOT's current STIP is a rolling, four-year plan, the Department is moving to a 10-year STIP. Emerging plans are for years one through four of the STIP's asset management projects to represent a four-year program of projects. Years five through 10 would represent a list of "needs" for meeting asset targets.

Federal regulations also require Colorado's five Metropolitan Planning Organizations (MPOs) to create their own transportation improvement programs. Each individual MPO creates its own formal process for improvement plan development, and these are integrated into CDOT's annual improvement plan without modification.

Before the Transportation Commission adopts the annual improvement plan, it releases a draft document for public review and comment, which includes a public hearing. The Transportation Commission receives and incorporates comments prior to final adoption of this plan. After adoption, the improvement plan is sent to the Federal Highway Administration and the Federal Transit Administration for final approval. Subsequent to its approval, the plan may be amended. Any major change requires public review and federal approval.

2.0 Risk Management

The threats that CDOT faces and the Department's approach to risk management are evolving rapidly. Age-old hazards—wildfires, floods, rockfall and more—continue to take their toll on Colorado's highways even as 21st Century threats such as ransomware put CDOT to the test.

FHWA rulemaking defines risk as the "positive or negative effects of uncertainty or variability upon agency objectives." Risk management is defined as the "process and framework for identifying, evaluating, and managing potential [threats]."

This section describes risk-management processes in place, including how CDOT identifies threats, assesses likelihood and consequences, and develops and prioritizes risk-management actions. As required by FHWA, the section also describes the agency's approach for identifying and addressing assets damaged twice or more in emergency events. Finally, Appendix 2 of this plan features CDOT's risk register, which has been updated for 2019.

Two events in recent CDOT history have highlighted the importance of risk management:

- A seven-day flood struck Colorado in 2013, leaving behind destruction spanning some 2,380 square miles. More than 3,000 evacuations were performed, more than 17,000 homes were damaged, and an estimated 1,800 homes were destroyed. The Colorado roadway network required more than $700 million in repairs.

- Hackers in Iran allegedly activated a ransomware malware virus within the CDOT computer network in February 2018. The attack delayed advertisement of CDOT projects, disrupted maintenance work activities and rendered data used for asset management inaccessible. The Department responded by shutting down its network, disrupting staff workflow, electronic data files, internal and external applications, and the server network. By mid-March 2018, 1,274 of CDOT's 3,272 laptops were infected and required reimaging. The Department also faced restoring 339 servers and 158 databases, among other repairs.

CDOT's Resilience Program and I-70 Pilot Project

*CDOT's efforts to address risks in asset management align with a Department-wide focus on resilience. This focus stems partly from Colorado's floods of 2013, which caused CDOT to think more deliberately about resilience and resulted in CDOT's Interstate 70 Risk and Resilience Pilot. The pilot, completed in 2018, created two categories of risks: **owner risk**, or CDOT's cost to replace or repair a damaged asset, and **user risk**, or the cost to drivers for detours and delays.*

The pilot project produced a rich data set that quantified the annualized risk cost for CDOT's assets on I-70 (e.g., bridges, roads, tunnels, culverts and walls) from a variety of threats (e.g., avalanche, flood, fire, rockfall, landslide and high wind). Going forward, the Department hopes to develop risk data for other state highways in Colorado, similar to what the pilot project produced for I-70.

The pilot demonstrated how CDOT could use the risk data to make decisions about which assets to target for improvements, and how it could optimize investment decisions by evaluating them on a benefit-cost basis.

(Continued)

This section of the RB-AMP identifies, assesses, evaluates, and prioritizes CDOT's asset-management threats and summarizes how risk-management processes and policies will eliminate, mitigate or incorporate the threats within asset-management operations and investment strategies. The Department's objective is not to avoid all threats, but to acknowledge them in the system and outline how resources may be allocated and actions taken based on acceptable levels of risk tolerance.

CDOT's Transportation Commission in November 2018 adopted *Policy Directive 1905.0—Building Resilience into Transportation Infrastructure and Operations*. The directive established the CDOT Resilience Program *(see sidebar beginning on previous page)* and directed CDOT to incorporate resilience into strategic decisions about transportation assets and operations.

The Department has defined key cornerstones for considering risk as an integral part of its asset-management program. These include:

1. An approach to managing risk across various levels—including agency, programmatic, and project/asset levels.
2. The development of CDOT's risk register to establish risk-management priorities across the Department.
3. A comprehensive decision-making process that includes risk management and resilience as a part of budget setting for each asset.

This approach to risk management considers the following items in identifying and quantifying risk-based opportunities:

- Broad range of threats—their probabilities and potential consequences.
- Mitigation opportunities—defined in terms of their benefits and costs.
- Geographic and/or corridor factors—considered in packaging and evaluating risk-management projects.

As part of the overall approach to implementing risk management, the method for characterizing and evaluating risk-based opportunities is critical. Therefore, CDOT has quantified its risks in terms of likelihood probabilities, impacts, and level of CDOT vulnerability. Benefits and cost analysis is being used to evaluate the effectiveness of mitigation

(Continued)

*CDOT followed the project by creating the **CDOT Resilience Program** in late 2018. The program helps incorporate resilience into strategic decisions about CDOT's transportation assets and operations. The program's current work includes:*

***1. Risk and Resilience Standard Project**—Launched in 2019, this two-year effort will develop a standard methodology for risk assessments for highway assets in Colorado, leveraging processes used in the I-70 Risk and Resilience Pilot. The project covers three asset classes (roads, bridges and culverts) and three threat types (rockfall, flood and fire/debris flow). The project will produce a guidebook for completing future risk assessments.*

***2. Business Process Project**—This project, a 12-month effort scheduled to kick off in summer 2019, will help CDOT identify how and when data from risk assessments should inform CDOT's day-to-day activities across all agency functions, from planning to asset management, scoping, engineering, maintenance, operations, and more.*

***3. I-70 Results Prioritization**—An ongoing effort to prioritize and act upon threats identified by the I-70 pilot, this effort is led by CDOT's Resilience Program Coordinator, with assistance from a working group and asset managers.*

strategies for buying down risks. With this information, risk-based investments can potentially be compared and traded off against each other, and against performance-based investments, such as pavement, fleet, or building-preservation activities.

CDOT's asset managers have developed their annual treatment lists based on condition needs. The Department is currently refining processes and tools for incorporating risk management and resilience into asset-management treatment selection and prioritization. Some of these new processes and tools, which remain in draft form, are described in Section 2.6.

2.1 Threat Identification and CDOT's Risk Register

CDOT has taken several major steps to identify threats to the transportation system, focusing mainly on discussions and workshops attended by asset managers and other subject matter experts.

In 2013, asset managers and other staff supplied an initial list of threats that could impede CDOT from fulfilling its mission, hinder day-to-day operations, or affect asset condition. A follow-up exercise with the Transportation Asset Management Risk Task Force—a self-selected group of staff interested in risk—identified priority assets that served as a starting point for brainstorming a full list of potential threats to CDOT. The Department then created a risk register that has been updated several times. In 2018, CDOT reformed its Transportation Asset Management Risk Task Force to update and expand the register for this plan. The new task force, which comprised asset managers, project delivery teams, and other subject matter experts, met monthly to discuss processes for identifying top-priority risks and managing them.

CDOT's efforts at analyzing risk have been guided by documents including the National Cooperative Highway Research Program's *NCHRP Report 706*[3], the American Association of State Highway and Transportation Officials' (AASHTO) *Guide for Enterprise Risk Management*, and the International Organization for Standardization's *ISO 31000* 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.

CDOT has organized its risk register *(See Appendix 2)* into **social, environmental and economic** categories. Each category includes two levels of risk:

- **Agency (Strategic, Corporate) Threats—**Affect mission, vision, and overall results of the asset-management program. Examples include politics, public perception, reputation and levels of available revenue.
- **Programmatic (Business Line) Threats—**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 projects 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.

[3] Cambridge Systematics, *"NCHRP Report 706: Uses of Risk Management and Data Management to Support Target-Setting for Performance-Based Resource Allocation by Transportation Agencies."* Transportation Research Board, Washington, D.C., 2011.

Asset managers address project-level or asset-level risks—those that affect scope, cost, schedule, and quality of projects—within their specific asset groups. Examples include hazardous materials, geology, environmental issues, right-of-way issues, utilities, project-development delays, scope growth, cost overruns and more.

Project-specific threats are not included in the register for three reasons. First, many such threats are common across projects within an asset program, and thus are included in programmatic threats. Second, CDOT's Program Management Office (PMO) already identifies and tracks project-specific threats, particularly around project delivery. Finally, project-level threats often do not help in understanding and prioritizing *overall* risk to CDOT due to their targeted focus.

In addition to leveraging the work of Risk Task Force to identify risk, the risk register incorporates lessons and nomenclature from CDOT's Interstate 70 Corridor Risk and Resilience Pilot (Risk and Resiliency for Highways). The pilot project used a process called the Risk Analysis and Management for Critical Asset Protection (RAMCAP) Plus method for identifying risks. The RAMCAP process for threat characterization looks at three types of threats:

1. **Terrorism threats.**

2. **Dependency and proximity hazards**. These are "threats that could inhibit performance of the function or mission due to the depravation of key inputs or outputs (e.g., utilities, suppliers, employees, customers) and the threats posed by colocation with other assets, the damage of destruction of which would seriously impact the asset being assessed."[4]

3. **Natural hazards.**

The I-70 pilot project looked at nine physical threats: avalanche, flood (scour), flood (overtopping/debris), fire (wildland), landslide, rockslide, high wind, tornado, and bride strike from high vehicles.

CDOT plans to use the risk register as a key tool to record risk-management information and to analyze risk-management approaches and strategies. The Department is developing more efficient strategies for storing, managing and updating the register, including making the register available to relevant work units.

2.2 Assessing Risk Likelihood, Consequences, and Vulnerability

CDOT's approach to evaluating and prioritizing risks includes assessing likelihood, consequence, vulnerability and priority. The Department's Asset Management Risk Task Force and other Department experts in 2018 and 2019 updated scores for these variables for all threats in the risk register *(See Appendix 2)*. CDOT also added and scored new threats.

Before these updates, CDOT identified and evaluated risk by multiplying likelihood times consequence (Risk = Likelihood x Consequence). For the 2019 RB-AMP, CDOT began including the vulnerability variable in its risk scores. Adding vulnerability will help CDOT understand its true risk exposure to a threat event, including how prepared the Department is to deal with consequences and considerations.

[4] ASME Innovative Technologies Institute, LLC, *"All-Hazards Risk and Resilience: Prioritizing Critical Infrastructure Using the RAMCAP Plus Approach,"* Pg. 42. ASME, 2009, New York.

2.2.1 Calculation of Risk Scores

CDOT in 2019 updated its methodology for determining risk rankings by incorporating a formula for calculating "owner risk" that was developed in the Department's I-70 Pilot Project. Over the course of several workshops and meetings, which included various asset managers, the Risk Task Force, the TAM Oversight Committee, and input from other CDOT staff, the risk register was updated for all major agency and programmatic threat-asset pairs.

Overall risk scores are now calculated as follows:

Risk Score = T × C × V

T = Threat likelihood (probability) event will occur

C = Consequences and consideration of risk event

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

Risk scores under this formula range between one and 156.25. Compared to the Department's previous formula, the new method results in a wider range of risk scores, thereby offering more precision in ranking events. Each component of the overall risk score is discussed below.

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+ years, etc.) and assigned a numeric value from one to five based on a scaling rubric.

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.

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, travelling 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.

$$C = Os \times [(Ss + Ms + Ds + Fs)/4]$$

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, including 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.

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 or severe consequences. This meant their overall risk scores dropped when compared to previous evaluations. Conversely, risk scores rose for certain events that are infrequent or have low impacts. Inclusion of the new vulnerability variable was informed by CDOT's recent Interstate 70 pilot and the related Risk and Resiliency for Highways project, which featured a similar calculation.

2.3 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)
- **Take 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.

For example, the Department may treat the risk of fire or chemical spills in major tunnels by installing fire-suppression systems, by developing and implementing incident-management strategies, and by developing response plans.

CDOT's recent I-70 pilot project demonstrates the potential for future analysis of specific risk-management strategies. The project featured examples of mitigation plans 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). Benefit/cost ratios were calculated for alternative mitigation measures and reductions in annualized risk, expressed in dollars, were provided for each mitigation strategy.

2.4 Monitoring Risk

ISO 31000 guidelines state that organizations should clearly define responsibilities for monitoring and reviewing risks. Such monitoring can be ad hoc or periodic. The purpose of such monitoring and review include[5]:

- Ensuring risk controls mechanisms are effective and efficient in both 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 treatment and priorities.
- Identifying emerging or previously overlooked risks.

CDOT's Asset Management Risk Task Force has designed the risk register to identify and monitor top-priority risks. The register will be updated regularly as contexts and risk criteria change, or as risk-management efforts influence

[5] International Organization for Standardization, *"Risk Management—Principles and Guidelines."* International Organization for Standardization, ISO Technical Management Board Working Group, ISO 31000:20009(E), 2009, Switzerland. ISO.

overall risk exposure. The task force also will be establishing roles and responsibilities for risk management within CDOT and individual asset groups.

Various asset programs at CDOT maintain their own databases, inspection programs and other methods of monitoring and reviewing asset risk. The Asset Management Risk Task Force is reviewing these efforts and exploring opportunities for coordination between databases and other information sources. For example, CDOT's bridge program maintains an inventory of structures at risk, such as scour-critical bridges, bridges with low vertical clearances, bridges with load restrictions, bridges posted for load, bridges with leaking expansion joints, and bridges with unsealed or otherwise unprotected deck areas. CDOT maintains performance measures and targets focused on reducing the percentage of its bridges that fall into these risk categories. Similarly, CDOT's Geohazards asset program maintains an inventory of more than 1,300 geohazards sites, including landslides, rockfall sites, sinkholes and more. The inventory focuses largely on geohazard sites that have previously resulted in a risk impact to a CDOT roadway.

Finally, CDOT is developing a database to monitor the risk from assets that have sustained damage caused by emergency or other events. The Damaged-Asset Database will be critical in fulfilling CDOT's requirements under FHWA Final Rule 23 CFR 667—*Asset Management Plans and Periodic Evaluations of Facilities Repeatedly Requiring Repair and Reconstruction Due to Emergency Events*. The database and emerging processes that will help CDOT comply with Part 667 are discussed in the following pages.

2.5 Assets Repeatedly Damaged in Emergencies

To comply with FHWA Final Rule 23 CFR 667—*Asset Management Plans and Periodic Evaluations of Facilities Repeatedly Requiring Repair and Reconstruction Due to Emergency Events*—CDOT evaluated transportation assets within Colorado that had potentially sustained repeated damaged in emergency events.

To complete its evaluation, CDOT brought together asset managers and other experts to review records of NHS assets damaged by emergency events. This effort required CDOT, through its Transportation Asset Management Working Committee, to:

- Review requirements under 23 CFR Part 667.
- Review a Federal Emergency Management Agency (FEMA) list of 68 emergency declarations in the state since 1997. The vast majority of these declarations were related to fires, followed by storms (and resultant flooding) and snow.
- 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.

Asset managers used this data to determine whether there were CDOT projects in the area of an emergency event; whether each project was the result of damage caused by the event; and whether CDOT undertook more than one project at the location since 1997 due to damage associated with an emergency event. The Department's Office of Transportation Safety and Risk Management engaged in a similar process, comparing the information above to insurance claims data to see whether these records included evidence of assets damaged twice or more by emergency events. The Department initially focused its analysis on bridge and pavement assets as specified in 23 CFR 667.

Although this multi-stage effort identified assets on the NHS system damaged in emergencies, **no such assets were identified that had been damaged twice or more since 1997** due to an emergency event.

As mentioned in previous pages, the Department's Performance and Asset Management Branch has developed a database containing damaged assets identified so far, as well as a process to update the database as additional assets sustain damage in emergency events. Going forward, CDOT expects this database will play a key role in new processes to determine whether resiliency should be added to assets due for maintenance, rehabilitation, or other treatments.

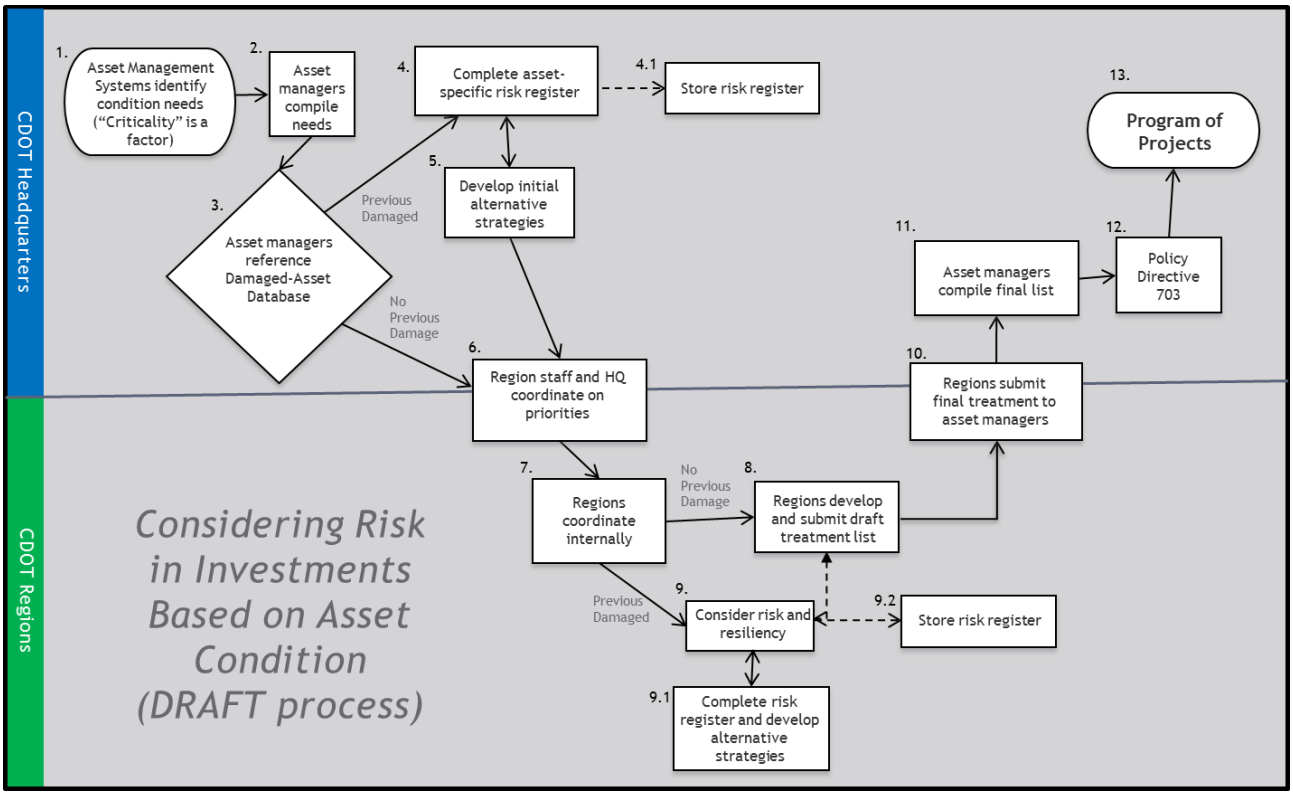
2.6 Considering Risk in Asset Management Investments

CDOT's processes for selecting and prioritizing asset-management projects have been driven primarily by comparing asset conditions with the benefits of treatments such as preventive maintenance, rehabilitation or reconstruction. However, the Department increasingly sees value in using other CDOT goal areas—safety, mobility, risk, and others—to drive investment decisions.

Similarly, CDOT's Policy Directive 1905.0 directs the Department to incorporate "resilience in strategic decisions regarding transportation assets and operations." Moreover, FHWA Final Rule 23 CFR 667 requires DOTs to determine whether there are "reasonable alternatives to roads, highways, and bridges that have required repair and reconstruction activities on two or more occasions due to emergency events."

To that end, CDOT is developing processes to incorporate considerations of risk into project-selection and prioritization. The illustrative process below provides a framework that demonstrates how various tools developed for risk-based analysis—including tools that address the Department's Policy Directive 1905.0 and 23 CFR 515.7 and 667.1—may be integrated into decision-making processes for asset management investments. Generally, the process shows how CDOT will integrate its risk-and-resilience formula, its database of damaged assets, its risk register, and the development of reasonable alternative approaches for managing risks for damaged assets.

Figure 3: Draft Process for Considering Risk in Asset Management Investments



The steps below further describe the process in Figure 3 for integrating risk-based analysis into CDOT's asset management investment decisions.

1. **Asset management system identifies condition needs**: The Asset Investment Management System (AIMS), or another CDOT asset management system, will analyze the Department's asset inventory and create a list of recommended asset treatments based on asset condition, geographic criticality, and available budget. Criticality is a measure of the importance of an asset to the resilience of the system. Asset criticality is based on location, as every segment of mainline roadway is given a score based on the matrix in Table 1.[6] See CDOT's Criticality Map in Appendix 1 of this report.

Table 1: Criticality Scoring Matrix

Criteria	Criticality Score					
	1 Very Low Impact	2 Low Impact	3 Moderate Impact	4 High Impact	5 Very High Impact	Weight
AADT	40 - 720	721 - 1,900	1,901 - 4,600	4,601 - 15,000	>15,000	1/6
AASHTO Roadway Classification	Minor Collectors	Major Collectors	Minor Arterial	Principal Arterial	Interstate Freeway Expressway	1/6
Freight ($M)	<=4,422	6,423 - 6,513	6,514 - 6,685	6,686 - 8,806	>8,806	1/6
Tourism ($M)	<152	153 - 479	480 - 1,050	1,051 - 3,414	>3,414	1/6
SoVI	(-9.69) - (-2.93)	(-2.92) - (-1.24)	(-1.23) - 0.67	0.68 - 2.51	2.52 - 6.23	1/6
Redundancy (CDOT 2015v)	4.51 - 50.5	3.01 - 4.5	2.01 - 3	1.51 - 2.0	1.0 - 1.5	1/6

2. **Asset managers compile needs**: Individual asset class managers will analyze and use the recommended treatment list, along with other information, as a starting point for compiling and creating a treatment list that aligns with the performance measure and target for the asset.

3. **Asset managers reference damaged-asset database:** Asset managers will consult the damaged-asset database CDOT is developing. Upon identifying a previously damaged asset, the asset class manager will determine if a common, reasonable alternative exists to mitigate against future risk to these assets. An example would be installing riprap to a bridge damaged by scour.

    A. If the **asset has been previously damaged**, go to Step 4 and 5

    B. If the **asset has no previous damage**, skip to Step 6

4. **Complete asset-specific risk register:** If the asset is found in the damaged-asset database, the asset class manager will develop a risk register for the asset. All significant threats to the asset will be identified.

5. **Develop alternate risk-management strategies/update main CDOT risk register:** Once the asset manager has identified all potential threats associated with the asset, they will use the risk register to perform a

[6] *Criteria in Table 1 include Average Annual Daily Traffic (AADT); the Association of American State Highway and Transportation Officials' "Roadway Classification factor"; freight value per ton at the county level in millions of dollars per year; tourism dollars generated at the county level in millions of dollars per year (Colorado Tourism Office June 2015 Report); Social Vulnerability Index (SoVI) at the county level (University of South Carolina Hazards & Vulnerability Research Institute 2010-14); and system redundancy.*

vulnerability assessment (using the method from the I-70 Pilot Project), by which reasonable alternative strategies are analyzed to evaluate their effect on the vulnerability component of the risk score. If the asset has multiple threats, threats with higher risk scores or multiple risk components (likelihood, consequence, or vulnerability) should be prioritized.

Figure 4: Vulnerability Assessment Formula

CDOT Risk and Resiliency Vulnerability Assessment Formula

$$Risk = C \times V \times T \qquad Equation\ 1$$

Where,

R = Potential loss due to analyzed event, $
C = Outcome of an event occurrence, $
V = Given event has occurred, probability of that estimated consequences will be realized, %
T = Likelihood event will occur, %

6. **Region staff and CDOT headquarters coordinate on priorities:** Asset class managers and CDOT Region staff will communicate on strategic needs and potential threats through the treatment lists, risk registers, and initial alternative approaches developed thus far.

7. **Regions coordinate internally:** **CDOT** Region staff will engage all necessary stakeholders when evaluating treatment options (including any reasonable alternative strategies developed by the asset class managers for previously damaged assets).

    a. If an **asset has been previously damaged**, go to Step 9

    b. If the **asset has no previous damage**, skip to Step 10

8. **Regions develop/submit draft treatment list:** Through consultation and coordination with asset class managers and other Region stakeholders, the Region staff develop a prioritized list of projects (one or more combined treatments). At this time, the Region staff determine if there are any reasonable alternative strategies that can be delivered to lower asset and system risk, which is identified and analyzed in the risk register.

9. **Complete asset-specific risk register and develop alternative risk-mitigation strategies:** Region staff will evaluate whether any of the initial reasonable alternative strategies identified by the asset class manager are preferred treatment options. Region staff will coordinate with other asset class managers and stakeholders to ascertain if the desired treatments can be combined to optimize CDOT resources, and/or achieve more significant reduction in overall asset and system risk. This process should also include consultation with other Regional staff, and include:

    a. **Completion of asset-specific risk register:** Once Regions have narrowed down their treatment requests, they will evaluate each identified asset within the list for risks. They should develop an asset-specific register that will attempt to identify and catalogue all threats potentially affecting that asset and roadway segment.

    b. **Development of reasonable alternative risk-management strategies:** Once the Region has identified potential threats associated with this asset and roadway segment, the Region should evaluate potential risk-management strategies. It is important that this process takes a holistic look at the asset, its function, interdependence and previously adopted resiliency efforts. Additional reasonable alternative strategies should be identified and analyzed. Should an asset have multiple threats, threats with higher total risk scores or risk components (e.g., likelihood, consequence, or

vulnerability) should be prioritized. Once a management strategy has been chosen, the Region staff should update the overall CDOT risk register to show how the selected treatment will impact (i.e., consequences or vulnerability) the risk score.

10. **Regions submit their final treatment list to asset managers:** Region staff will provide their prioritized list of treatments to the CDOT asset class manager.

11. **Asset class managers compile final list:** Following procedures established for their asset class, CDOT asset class managers will evaluate all Regional treatment requests to create a statewide program of projects for their asset class.

12. **Policy Directive 703:** CDOT headquarters staff will ensure the compiled final list of treatments for all asset classes complies with necessary policy directives. PD-703 outlines the policy by which the Department will approve the program of asset-management projects.

13. **Program of projects:** With Transportation Commission approval of the annual budget and asset-management planning budgets, CDOT staff will begin delivery of the program of projects.

3.0 Asset Inventory and Condition

Colorado ranked 13th best for bridge condition out of all 50 states and Washington, D.C., in 2017, as measured by the percentage of National Highway System (NHS) deck area in the state in "good" condition. Meanwhile, the state ranked 37th best in the nation for pavement condition in 2017, as measured by International Roughness Index scores for NHS pavement.[7]

Under federal requirements, this asset-management plan must include an inventory of National Highway System (NHS) pavement and bridge assets, as well as conditions of those assets under new National Performance Measures. These requirements extend not only to NHS assets owned by CDOT, but to those owned by entities such as municipalities and counties as well. This section meets those requirements. In addition, the section provides a summary of CDOT-owned assets according to the Department's internal metrics.

3.1 Pavement

3.1.1 Pavement Inventory

The NHS in Colorado comprises 13,470 lane miles of pavement, with the Interstate system accounting for about 27 percent of the total lane miles. CDOT is responsible for a highway system encompassing 22,970 total lane miles of pavement, or about 9,077 centerline miles.

CDOT owns 87 percent of the NHS, by lane miles, while municipalities and counties own 13 percent. CDOT also maintains 9,500 lane miles of pavement not included in the NHS.

Table 2: CDOT and NHS Pavement Assets by Classification, 2017

Classification	Centerline Miles	Lane Miles
Interstates (CDOT)	952	4,143
CDOT NHS (includes Interstates)	4,414	13,470
CDOT non-NHS	4,663	9,500
Total CDOT System	**9,077**	**22,970**
Off-System NHS	494	1,950
Total NHS	**4,908**	**15,420**

Source: CDOT

7 This ranking is determined by the percentage of National Highway System centerline miles, including Interstates, in "good" condition, as defined solely on the International Roughness Index.

3.1.2 NHS Pavement Condition

New National Performance Measures evaluate pavement in terms of Good, Fair and Poor condition. Whether a pavement is rated Good, Fair or Poor is determined by scores for the following factors: International Roughness Index (IRI), Present Serviceability Rating (PSR), rutting, faulting, and fatigue/alligator cracking percentage. *(See Table 3 below and Figure 7 in the following pages.)* If IRI, cracking and rutting/faulting are all rated Good, the pavement is rated Good. If two or more factors (IRI, cracking and rutting/faulting) are rated Poor, the pavement is rated Poor. All other pavements are rated Fair.

About 44 percent of Interstate pavement in Colorado was in Good condition in 2018, while about 53 percent was in Fair condition, and 2.5 percent was in Poor condition. Meanwhile, about 42 percent of non-Interstate NHS pavement in the state was in Good condition in 2018, 55 percent of such pavement was in Fair condition, and 3 percent was in Poor condition. The Department does not have reliable historical information for these metrics to describe trends. See the following page for a map of NHS pavement in Colorado according to the new metrics.

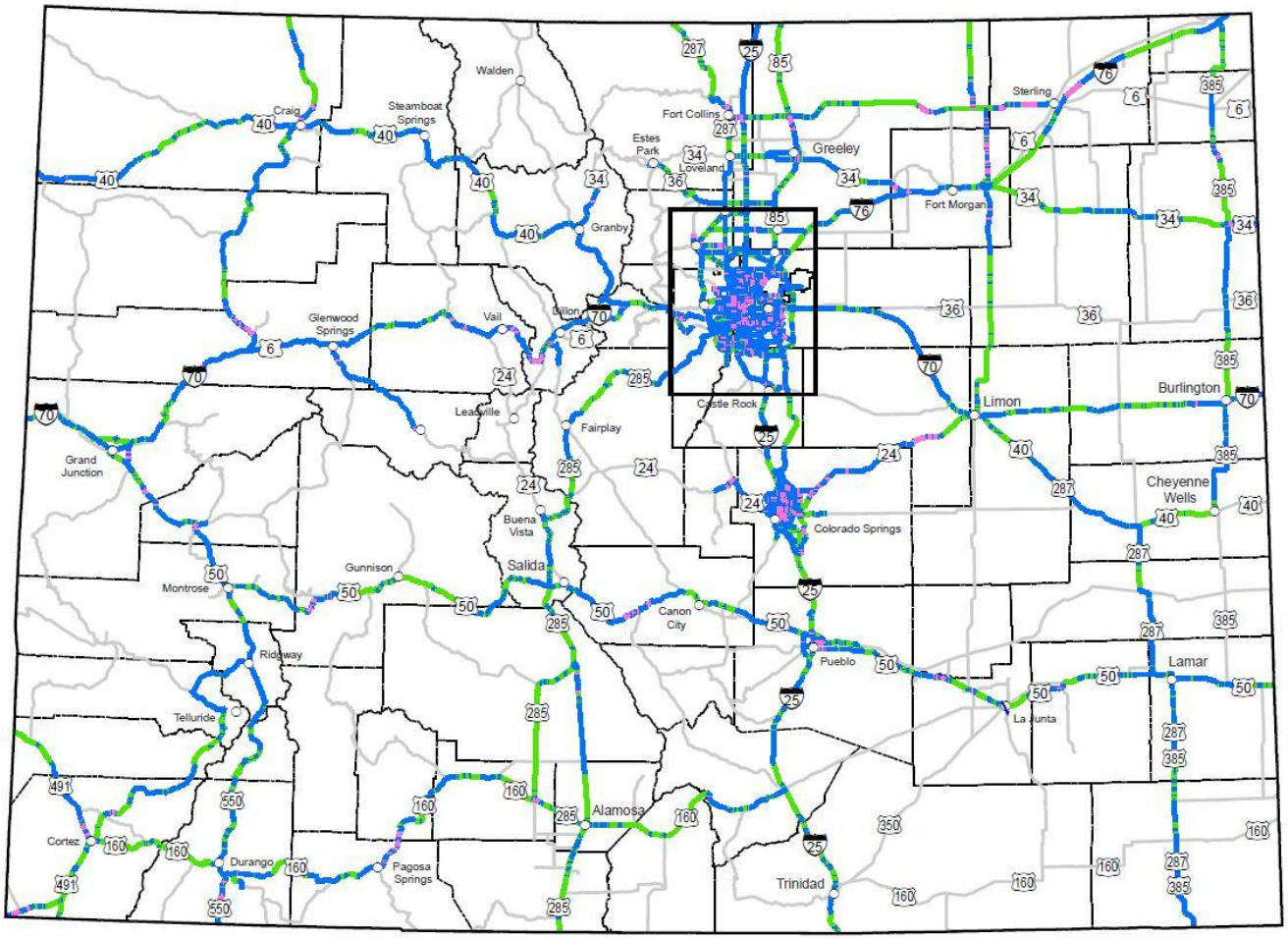
Table 3: Federal Pavement Metric Thresholds

Rating	Good	Fair	Poor
IRI (inches/mile)	<95	95-170	>170
PSR* (0.0-5.0 value)	≥4.0	2.0-4.0	≤2.0
Cracking Percent (%)	<5	Continuously Reinforced Concrete (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

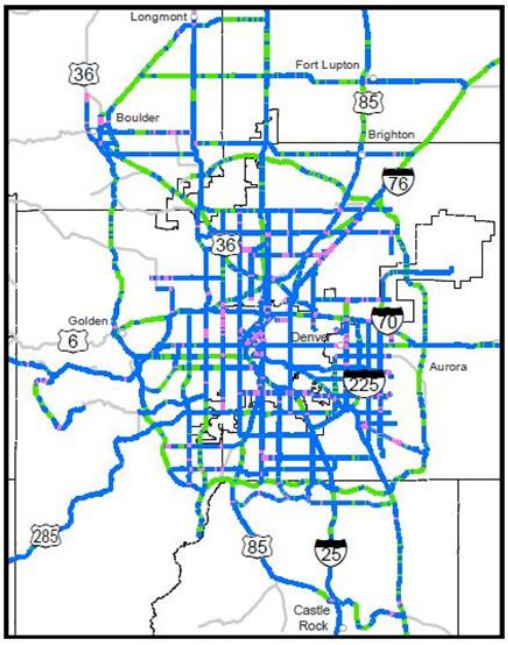
Note: PSR may be used only on routes with posted speed limit <40 mph.

Source: FHWA

Figure 5: Colorado and Denver Metro NHS Pavement Condition



The map above shows the condition of National Highway System pavement in Colorado according to FHWA's definitions for Good, Fair and Poor condition. The map at right shows the condition of NHS pavements in the Denver area.



NHS Pavement Condition

- Good
- Fair
- Poor
- Not on NHS
- Cities/Towns
- Highway
- Counties

3.1.3 Drivability Life Measure and FHWA Pavement Distress Data

While National Performance Metrics rate pavements as Good, Fair or Poor, CDOT's primary internal metric for pavement condition is Drivability Life (DL). Drivability Life is an indication, in years, of how long a highway will have acceptable driving conditions. An acceptable driving condition is a function of smoothness and safety, as determined by the amount of pavement cracking and the depth of rutting. Unacceptable pavement condition does not mean a roadway is impassable, but it does mean that drivers must reduce speeds to compensate for less-than-desirable driving conditions, navigate around potholes, or endure rough rides.

Drivability standards for condition assessment vary between highway classifications, with Interstates having the highest standards. To determine the Drivability Life for a segment of highway (0.5–5.0 miles in length), CDOT conducts a trend analysis using the following distresses:

- International Roughness Index (IRI);
- Rutting;
- Transverse cracking (low, moderate, and high severities);
- Longitudinal cracking (low, moderate, and high severities);
- Fatigue cracking (for asphalt only) (low, moderate, and high severities); and
- Corner break (for concrete only) (low, moderate, and high severities).

The predicted time at which any one of these distresses surpasses a predefined drivability threshold defines the Drivability Life of that segment. Drivability Life is then grouped into three categories:

- High Drivability Life—More than 10 years
- Moderate Drivability Life—Four to 10 years
- Low Drivability Life—Three or fewer years

3.1.4 Drivability Life and National Performance Metric

As of 2018, FHWA requires all states to collect pavement distress data on all Interstate and NHS pavements and to calculate the percent of NHS miles in Good, Fair, and Poor condition.

Readers should note that the data and calculations used by FHWA are different from CDOT's Drivability Life data and calculations. CDOT plans to continue managing pavement condition using the Drivability Life metric. At the same time, the Department is developing new analyses within its asset-management modeling system that will allow CDOT to forecast pavement condition using the national performance measures and to better understand the relationship between the national metric and Drivability Life.

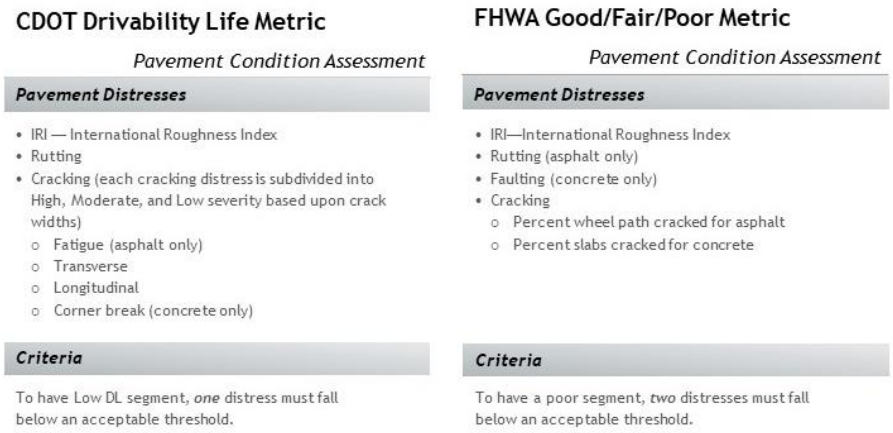
FHWA's Good/Fair/Poor ratings and CDOT's High/Moderate/Fair Drivability Life ratings are based on the same or similar distress types. *(See Figure 7 on following page.)* While the two measurements do not have direct,

mathematical correlations, improving the roadway condition under Drivability Life standards also should help CDOT influence performance under the national metric.

While the two assessments incorporate similar data, the processing of that data differs significantly. CDOT tracks pavement deterioration rates over time and uses those trends to calculate Drivability Life performance. Good/Fair/Poor condition is not based on deterioration rates, but upon raw distress ranges and categorization.

CDOT also uses the two metrics differently. Drivability Life is used to identify current CDOT pavement conditions as they relate to driver experience, to predict future conditions, and to identify cost-effective solutions for maintaining pavement conditions. Presently, Good/Fair/Poor is used at CDOT for federal reporting purposes, including monitoring progress of the National Highway System, including off-system pavement, toward meeting federally required performance targets.

Figure 6: Comparison of Drivability Life (DL) and FHWA Metric Components



Source: CDOT

Figure 7. Overlap of CDOT Drivability Life and FHWA Good/Fair/Poor Scales

Source: CDOT

3.1.5 Condition Trends

CDOT lacks sufficient data to provide condition trends for the entire National Highway System or the Interstate according to Good, Fair and Poor conditions. This section therefore describes conditions of the CDOT-owned state highway system according to CDOT's Drivability Life metric.

In 2018, 80 percent of sampled pavement on Colorado's State Highway System had High or Moderate Drivability Life. This means CDOT is achieving its fiscally constrained goal for this metric, which also is 80 percent. State Highway System pavement condition has remained near this condition level since 2015 *(see Table 4 below)*. This stability has been due in part to slower-than-expected deterioration and technical updates to CDOT's pavement management system.

CDOT in recent years has been performing more pavement preservation treatments, which are cost-effective surface improvements that increase the Drivability Life of pavement at a low cost. These treatments are effective in improving roads from Moderate to High Drivability Life.

Table 4: Condition of State Highway System Pavements by Drivability Life

	High	Moderate	Low	High and Moderate
2014	14%	60%	26%	74%
2015	19%	60%	20%	80%
2016	23%	58%	19%	81%
2017	23%	57%	19%	81%
2018	21%	59%	20%	80%

3.2 Bridges

3.2.1 Bridge Inventory

CDOT owns and maintains 3,451 bridges, or about 33.5 million square feet of bridge-deck area, as of 2018. There are 2,622 bridges on the NHS system in Colorado, or about 29.9 million square feet of bridge deck area. CDOT owns 2,314 bridges on the NHS, or about 88 percent. About 12 percent is locally owned.

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 between abutments, spring lines of arches, extreme ends of openings for multiple boxes, or extreme ends of openings for multiple pipes.

The majority of CDOT's bridges are managed by CDOT's Staff Bridge Unit. However, the state of Colorado has created a unique structure for the control and maintenance of bridges in Poor condition. 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). CBE operates as a public-private enterprise within CDOT, with the Colorado Transportation Commission serving as the CBE Board.

The purpose of the CBE is to finance, repair, reconstruct, and replace bridges with a "Poor" rating. While the bridges remain state-owned, direct control and maintenance of structures transferred to the CBE are now

conducted by the enterprise. There are currently 114 CBE assets, of which 69 are on the NHS. Of the 114 bridges, 96 were replaced by CBE, and 18 were rehabilitated. CBE has its own prioritization process for selecting which poor-quality CDOT-owned bridges it will rehabilitate.

Table 5: Bridges Inventory

Asset	Number of Bridges	Deck Area (approx. square feet)
CDOT-owned Bridges	3,451	33.5 million
CDOT-owned NHS bridges	2,314	26.2 million
NHS bridges (CDOT and locally owned)	2,622	29.9 million

Source: CDOT

3.2.2 Bridge Condition

The conditions of bridges shown in this plan are based on ratings of factors defined in federal regulations. CDOT inspects the condition of major bridges and major culverts according to National Bridge Inspection Standards (NBIS). The NBIS provides a uniform set of 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.

Per current federal guidelines, CDOT assigns structures a condition of Good, Fair, or Poor based on the following criteria:

- The minimum NBIS condition rating of the deck, superstructure, or substructure for bridges.
- The NBIS condition rating for culverts.

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 (Figure 10). Bridges in Poor condition are classified as Structurally Deficient.

Figure 8: National Bridge Inspection Rating Scale

About 47 percent of deck area for bridges on the NHS in Colorado was in Good condition in 2018, while 49 percent was in Fair condition, and 4 percent was in Poor condition (Table 6). NHS inventory and condition data collected by Metropolitan Planning Organizations (MPOs) are summarized in Table 7 below.

Table 6: Colorado's NHS Bridges by 2018 Condition

	Good			Fair			Poor		
Classification	#	Ft2	%	#	Ft2	%	#	Ft2	%
Interstate	473	6,452,077	43%	594	7,730,567	52%	51	681,340	5%
Non-Interstate NHS	720	7,713,253	51%	734	6,902,431	46%	50	460,862	3%
Total NHS	1,193	14,165,330	47%	1,328	14,632,998	49%	101	1,142,202	4%

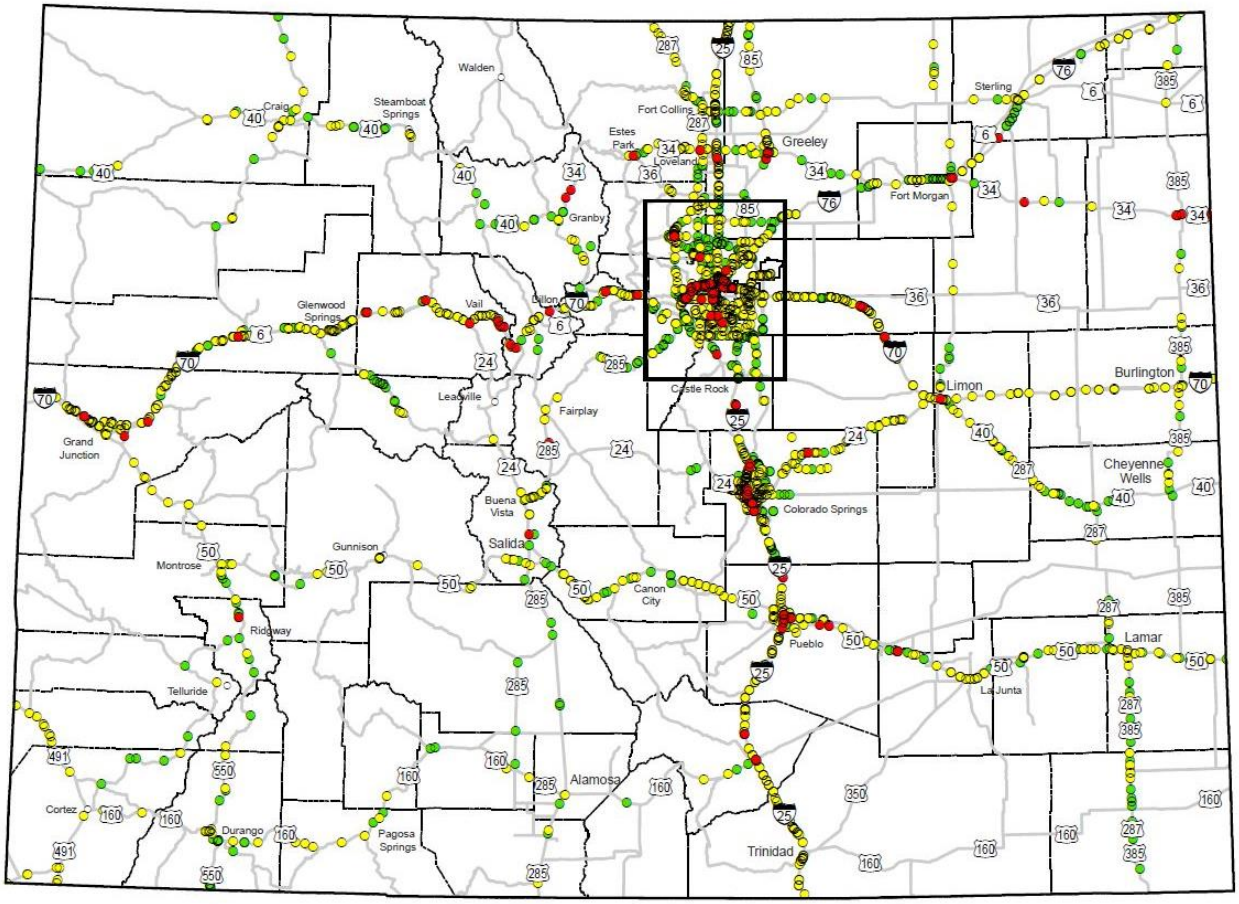
Source: CDOT

Table 7: Inventory of Colorado MPOs' NHS Bridges and 2018 Condition

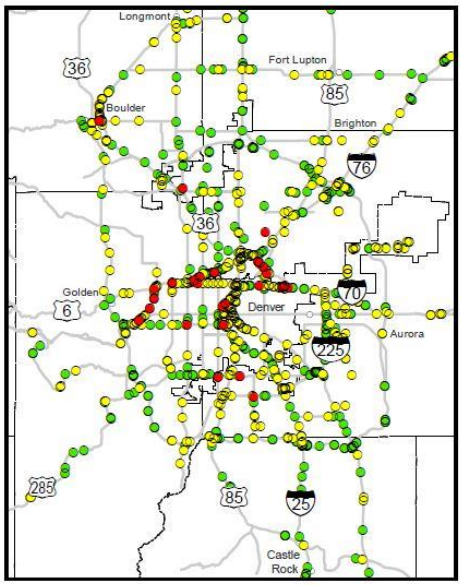
Agency	Metric	Total	Good	Fair	Poor
Denver Regional Council of Governments	Structures	920	487	403	30
	Deck Area (SF)	14,912,196	7,561,631	6,909,739	440,826
	% by Deck Area	100%	51%	46%	3%
North Front Range MPO	Structures	127	49	73	5
	Deck Area (SF)	985,263	451,235	476,616	57,412
	% by Deck Area	100%	46%	48%	6%
Pikes Peak Area Council of Governments	Structures	245	117	117	11
	Deck Area (SF)	3,078,847	1,577,218	1,413,105	88,524
	% by Deck Area	100%	51%	46%	3%
Pueblo Area Council of Governments	Structures	78	23	46	9
	Deck Area (SF)	1,015,091	386,173	478,713	150,205
	% by Deck Area	100%	38%	47%	15%
Grand Valley MPO	Structures	50	14	36	0
	Deck Area (SF)	468,554	166,935	301,619	0
	% by Deck Area	100%	36%	64%	0

Source: CDOT

Figure 9: Colorado and Denver Metro NHS Bridge Condition



The map above shows the condition of National Highway System bridges in Colorado according to FHWA's definitions for Good, Fair and Poor condition. The map at right shows the condition of NHS bridges in the Denver area.



NHS Bridge Condition

- Good
- Fair
- Poor

- Cities/Towns
- Highway
- Counties

3.2.3 Bridge Trends

CDOT's $1.2 billion Central 70 project will improve 10 miles along the Interstate and replace one of CDOT's largest bridges. This bridge, which comprises about 1 percent of all bridge deck area in Colorado and almost 2 percent of total NHS bridge deck area, fell from fair to poor condition in 2019. The percentage of 2019 poor deck area for this structure has not been included in condition data for this document, which is based primarily on 2018 data, for consistency. The Central 70 project will replace this structure and other poor deck area that, combined, represent about a third of CDOT's total "poor" deck area as of 2019. The project began in July 2018 and is expected to be completed by 2022.

Figure 10 shows the percentage of deck area on NHS bridges in Good, Fair, and Poor condition over the past 10 years. Since 2008, the percentage of deck area on structures in Poor and Good condition has decreased. If historical trends continue, the percentage of deck area in Fair condition will continue to increase and far exceed the percentage of structures in Good condition.

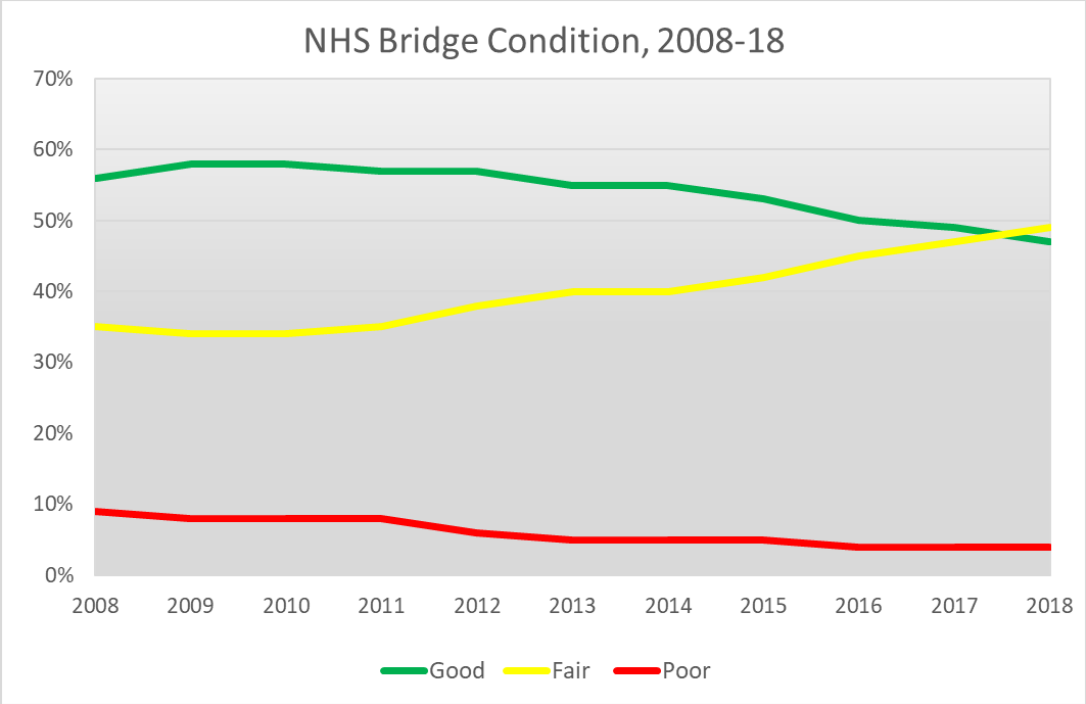
The federal FAST Act establishes a minimum condition level for bridges on the NHS. Specifically, the percentage of deck area on structures that are Poor is not to exceed 10 percent.[8] As of 2018, Colorado is outperforming this standard, with about 4 percent of total NHS deck area on Poor bridges.

As a whole, bridges on the NHS currently are in relatively good condition. However, many structures built in the 1950s are past the end of their designed service lives of 50 years. They will require extensive rehabilitation or replacement in the near- to mid-term future due to natural deterioration. 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.

CDOT's $1.2 billion Central 70 project will improve 10 miles along the Interstate and replace one of CDOT's largest bridges. This bridge, which comprises about 1 percent of all bridge deck area in Colorado and almost 2 percent of total NHS bridge deck area, fell from fair to poor condition in 2019. The percentage of 2019 poor deck area for this structure has not been included in condition data for this document, which is based primarily on 2018 data, for consistency. The Central 70 project will replace this structure and other poor deck area that, combined, represent about a third of CDOT's total "poor" deck area as of 2019. The project began in July 2018 and is expected to be completed by 2022.

[8] The conditions of "Poor" and "Structurally Deficient" are now synonymous, despite historically having different definitions.

Figure 10: Colorado NHS Bridge Condition



Source: CDOT

4.0 Performance Targets and Gaps

The federal Moving Ahead for Progress in the 21st Century Act (MAP-21) ushered in a performance- and outcome-based transportation program. The federal Fixing America's Surface Transportation Act (FAST) of 2015 continued MAP-21's overall performance management approach and encouraged CDOT and other DOTs to invest resources in projects that support progress toward national goals. Along with developing an asset management plan, CDOT is required to establish performance targets for areas including NHS pavements and bridges, regardless of ownership, using national performance measures. These performance targets must be consistent with Colorado's own transportation asset-management objectives.

4.1 Performance Measures

This section examines federally established performance measures for NHS pavement and bridges, regardless of ownership, as well as CDOT's internal performance measures for pavement and bridges. This section also analyzes gaps between current and target performance levels.

FHWA's final rule for NHS pavement and bridge condition metrics (23 CFR Part 490) established performance measures for CDOT to use in delivering the National Highway Performance Program (NHPP). For pavement, the rule requires CDOT to report the percentages of both Interstate and non-Interstate NHS pavement in Good condition and Poor condition. For bridges, CDOT must report the percentage of NHS deck area on bridges in Good and Poor condition.

4.1.1 Performance Targets and Performance Gaps

National Measures, Targets and Gaps

Table 8 below presents CDOT's current asset performance and performance gaps based on National Performance Measures for NHS pavements and bridges. Currently, there is a performance gap for each pavement target. CDOT is currently exceeding its NHS bridge targets, so no gaps exist.

CDOT has long been setting performance targets and tracking progress against them. The Department regularly evaluates various investment strategies produced by its Asset Investment Management System (AIMS) to determine the best strategy to meet its condition 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. CDOT is currently developing analyses within AIMS to address National Performance Measures.

Table 8: Two- and Four-Year Pavement and Bridge Performance Targets and Gaps

	Current Performance (FY18)	FY20 Target	FY22 Target	Performance Gap (Current vs. FY20 Target)	Performance Gap (Current vs. FY22 target)
Pavements					
Percentage of pavements on the Interstate System in **Good** Condition	44%	46%	47%	2 percentage points	3 percentage points
Percentage of pavements on the Interstate System in **Poor** Condition	2.5%	1%	1%	1.5 points	1.5 points
Percentage of pavements on the non-Interstate NHS in **Good** Condition	42%	50%	51%	8 points	9 points
Percentage of pavements on the non-Interstate NHS in **Poor** Condition	3.0%	1%	2%	2 points	1 point
Bridges					
Percentage of NHS bridges, by deck area, in **Good** condition	47%	45%	44%	- 2 points	- 3 points
Percentage of NHS bridges, by deck area, in **Poor** condition	4%	4%	4%	No gap	No gap

*Note: FHWA defines a performance gap as the gap "between the current asset condition and State DOT targets for asset condition." Negative points are shown above when current asset condition is **better** than the target level.*

In addition to identifying physical-condition gaps, FHWA requires state DOTs' asset-management plans to identify gaps in the effectiveness of the NHS in providing for the safe and efficient movement of people and goods.

In the safety area, the Department maintains programs that identify and implement mitigation strategies at locations with the potential for significant crash reduction, such as the Hot Spots program in the Division of Engineering. Of the 648 fatalities that occurred on Colorado roadways in 2017, 365 (or 56 percent) were on NHS roadways, according to data from the national Fatality Analysis Reporting System (FARS). However, about 63 percent of Vehicle Miles Traveled in Colorado occurred on NHS roadways that year.

In the system performance area, the Department has established NHS-specific goals for FHWA's National Performance Measures for Level of Travel-Time Reliability (LOTTR). The goals are for 81 percent of the person miles traveled on the Interstate system to be reliable. For the non-Interstate NHS, the goal is for at least 64 percent of the person miles traveled to be reliable. CDOT's actual performance was below its goal for Interstates in 2018, with 78 percent of person miles traveled on the Interstates reliable. The Department was exceeding its goal for non-Interstate NHS in 2018, with about 87 percent of the person miles traveled being reliable.

In addition to these targets, the Department's Performance Plan for Fiscal Year 2019-20 will showcase new investment strategies to provide for the efficient movement of people and goods. These efforts include:

- A strategic safety program that includes $11.3 million in 2019 for safety-related infrastructure improvements, such as more six-inch striping, cable guardrail, and rumble strips. Deployment of wider, six-inch striping can improve driver awareness and is a relatively low-cost strategy to help prevent crashes related to vehicles running off the road and crossing over lanes.
- Increasing Traffic Incident Management coalitions with the Department of Public Safety and Colorado State Patrol to cover 9,000 lane miles by the end of state fiscal year 2020 across the state. The coalitions will employ best practices to quickly clear incidents and return roadways to normal traffic.

Coordination with Local and Regional Partners

CDOT officially committed to its statewide targets for FHWA-required performance measures for infrastructure condition (PM2) and system performance (PM3) in 2018. The Department and regional FHWA representatives communicated regularly with Colorado's MPOs about the target-setting process, particularly through monthly "Statewide MPO Meetings" at CDOT's headquarters.

CDOT will continue working with the MPOs to develop a coordinated data-sharing process and to ensure there is an agreement on responsibilities. Since early 2018, CDOT has been providing, and will continue to provide, historical data on the FHWA-required metrics to help MPOs understand current performance under the new metrics, especially for bridges and pavement. The Department maintains the most comprehensive data on these assets, because it collects pavement and bridge condition data for the full NHS.

In addition, the Department in the spring of 2019 collaborated with the cities of Denver and Colorado Springs to understand those cities' future investments in NHS pavement and bridges. CDOT will seek to integrate such spending information into analyses it develops for forecasting performance under National Performance Measures.

CDOT Policy Directive 14 Targets and Gaps

In addition to goals for National Performance Measures, CDOT maintains internal metrics and goals for pavement and bridges (and other assets) in the Department's Policy Directive 14. PD-14 contains objectives and performance targets set by the Transportation Commission that guide the distribution of CDOT's financial resources. Objectives, known as goals in the directive, align with MAP-21 National Performance Areas, such as infrastructure condition. The Department's infrastructure objective, for all asset categories, is "to preserve the transportation infrastructure condition to ensure safety and mobility at a least life cycle cost." This objective is consistent with risk-based asset management practices.

The following table outlines PD-14's current 10-year performance targets for pavement and bridges. These targets are stated for both the aspirational funding level and a fiscally constrained level. Aspirational funding levels are long-held goals of the Department and are set as part of the statewide planning process. These goals reflect a desired level of service should CDOT receive revenues beyond those projected. Fiscally constrained levels represent more realistic goals, understanding the impact of limited revenue and reduced buying power. This level shows an acceptable level of service within a more likely CDOT budget, and may increase or decrease slightly as a result of funding cycles. The table also shows CDOT's current performance gap, which represents the difference between current performance and CDOT's more fiscally constrained targets. "Negative" gaps mean that CDOT is performing better than its target.

Table 9: CDOT PD-14 Performance Targets for Pavement and Bridges

Asset	Measure	Current Performance (FY18)	Aspirational Target	Fiscally Constrained Target	Performance Gap (Current state vs. constrained target)
Pavements	Percentage high—moderate drivability life for Interstates based on condition standards and treatments set for traffic volume categories.	89%	90%	80%	-9 percentage points[9]
	Percentage high—moderate drivability life for CDOT-owned NHS, excluding Interstates based on condition standards and treatments set for traffic volume categories.	84%	90%	80%	-4 points
	Percentage high—moderate drivability life for state highway system based on condition standards and treatments set for traffic volume categories.	80%	90%	80%	No gap
Bridges	Percentage of deck area on structurally deficient CDOT-owned bridges.	4%	5%	10%	-6 points
	Percentage of deck area on structurally deficient bridges on the NHS.	4%	5%	10%	-6 points
	Percentage of CDOT-owned bridges over waterways that are scour critical.	6%	1%	5%	1 points
	Percentage of CDOT 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%	0.00%	1%	1 point
	Percentage of CDOT 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.	21%	12%	18%	3 points
	Percentage of CDOT-owned bridges posted for load.	0.4%	0.00%	0.10%	0.3 points
	Percentage of CDOT-owned bridges with a load restriction.	2.2%	0.00%	0.90%	1.3 points
	Percentage of leaking expansion joint by length on CDOT-owned bridges.	33%	15%	26%	7 points
	Percentage of CDOT-owned bridge deck area that is unsealed or otherwise unprotected.	40%	20%	35%	5 points

[9] Negative gaps or points mean that CDOT is outperforming its target.

Strategies for Closing Performance Gaps

CDOT regularly evaluates various investment strategies and funding levels, including by reviewing analyses from CDOT's Asset Investment Management System (AIMS), to determine the best strategy to meet condition targets. The Department 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 Policy Directive 14 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 pavement and bridges.

5.0 Life-Cycle Planning

Accounting for the full costs of planning, constructing and maintaining assets—and leveraging analysis across the CDOT system to project investment needs and set priorities—requires a complex network of information. Information, strategies and processes used by CDOT in life-cycle planning are described in this section.

Life-cycle planning is FHWA's term for all investments an agency makes in an asset over its useful life, and its decision-making processes for making such investments—including if and when to invest.

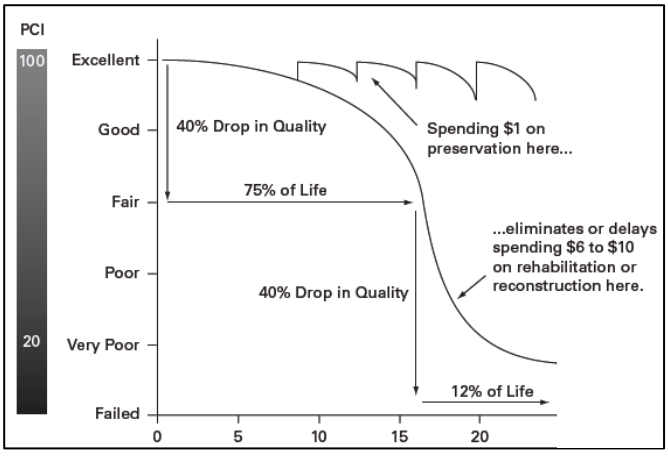
Life-cycle planning refers to investments an agency plans to make in an asset over its useful life. Life-cycle planning includes the agency's decision-making processes for making such investments, including if and when to invest. In describing CDOT's approach to life-cycle planning, this section includes a discussion of treatment costs and benefits, how deterioration is modeled and treatments are selected, and how management strategies minimize overall life-cycle costs.

Investments are made in assets at many points throughout their life cycles. The diversity of CDOT's assets dictates a range of analytical methods for understanding and optimizing these investments.

Some DOTs have accepted a "worst-first" approach to maintaining or replacing assets. CDOT does not see this as an optimal approach to life-cycle planning. A worst-first approach has an agency rank its assets from worst to best condition, and works down the list until funds are expended. Assets prioritized on a worst-first basis typically require reconstruction or replacement, which can be costly relative to rehabilitation or to preventive actions.

CDOT has adopted more cost-effective alternatives to the worst-first approach; these alternatives incorporate preventive activities, preservation and rehabilitation. As Figure 12 shows, preventive maintenance activities, asset preservation and rehabilitation slow the deterioration of an asset and prolong its life. As lifespan is extended, replacement can be delayed. As a result, preventive maintenance, preservation and rehabilitation strategies can drive down ownership costs and help the agency better forecast and plan for replacement time cycles.

Figure 11: 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

CDOT's lifecycle strategies and modeling assumptions will continue to evolve with changes in technology and climate. For example, many researchers[10] forecast that autonomous vehicles will increase vehicles miles traveled, such as due to an increase in use among disabled and elderly people. And sustained extreme heat in Colorado due to climate change may make pavements more vulnerable to buckling and stress the integrity of bridges.[11]

CDOT will continue to adapt to these conditions, such as by having its Materials and Geotechnical branch analyze materials for their resiliency to possible changes in climate, such as more precipitation and more extreme heat.[12] In addition, CDOT's current modeling approach for pavement is informed by traffic, temperature and other factors. Changes from climate change and autonomous vehicles could mean faster deterioration, which will necessitate changes in CDOT's deterioration curves and treatments for affected roadways.

5.1 Pavement Life-Cycle Planning

5.1.1 Life-cycle planning strategies

Conduct More Preventive Maintenance on Pavements

Preventive maintenance means applying lower-cost treatments at an appropriate time in the life of pavements to extend the performance of the roadway and reduce the likelihood of high-cost rehabilitation and reconstruction. Key preventive maintenance activities include performing crack sealing and filling, concrete joint sealing and filling, ultrathin asphalt overlays (≤1.5 inches), surface seals (chip seal, fog seal, etc.), microsurfaces, and patching. The programming of these activities (using surface treatment dollars) into the pavement management system has been completed, but will be routinely refined based on documented project cost and performance data.

Preventive maintenance treatments for Interstates, high-volume highways, and moderate-volume highways are modeled in one treatment category in the pavement asset-management software, and are typically triggered relatively early in the life of these pavements. Applying treatments from this preventive maintenance category adds three to six years of Drivability Life (DL) to a highway segment, depending upon the traffic loading (in Equivalent Single-Axle Loads, or ESALs). Preventive maintenance is not the only treatment type allowed on high- and moderate-volume roadways.

For low-volume roads, there are only two primary treatment types modeled in the pavement asset-management software. One is for surface seals, which are good for creating a new wearing surface and sealing the existing pavement from moisture infiltration. Surface seals are most effective when applied before DL deteriorates to zero years. While surface seals are very effective at covering cracks, they cannot improve rutting defects in the pavement surface or significantly improve smoothness (as measured by IRI). The other low-volume treatment type is thin asphalt treatment (i.e., microsurfacing, ultrathin overlays), which is more appropriate for areas of more significant distress and may be applied in surgical applications to isolated areas only.

[10] *See, for example, Fagnant, Daniel and Kockelman, Kara (2013). "Preparing a Nation for Autonomous Vehicles: Opportunities, Barriers and Policy Recommendations." Eno Center for Transportation. Washington, D.C.*
[11] *Gordon, Eric and Dennis Ojima, editors. "Colorado Climate Change and Vulnerability Study." The University of Colorado Boulder and Colorado State University. January 2015.*
[12] *Ibid.*

Prioritize Interstates and High- and Medium-Volume Roadways Over Other Roadways

CDOT has established pavement-condition targets (expressed as a percent of pavements with high or moderate DL) for Interstates, NHS, and the overall statewide highway system. While the percent target is the same for all categories of pavement, CDOT has developed different DL standards based on highway traffic volumes. Interstates and high- and medium-volume roadways have the highest standards, while low-volume roadways have lower acceptable DL standards. All acceptable DL standards consider the safety and serviceability needed by roadway users. Strategies for Interstate and high-volume roadways include all treatment types from maintenance to reconstruction. Medium-volume roadways include all treatment types from maintenance to minor rehabilitation. Treatment strategies for low-volume roadways focus primarily on thin surface treatments. Overall calculated project benefits in the pavement management software are influenced in direct proportion to traffic volume.

Achieve Economic Efficiencies by Coordinating Pavement Activities with Activities on Other Assets

Surface Treatment funds are intended to be invested in highway-surface improvements. Safety projects and capacity-improvement needs are funded from separate sources of money, so these needs are not modeled in the pavement management software. More generally, all management systems (bridge, pavements, rockfall, maintenance, etc.) work independently of each other. From an asset modeling perspective, project selection for one asset class is not impacted by modeling for a different asset class. Thus, a bridge-deck rehabilitation project is not combined with an adjacent pavement resurfacing project, nor a neighboring safety-improvement project. While this inter-asset, inter-need, and inter-investment coordination is not modeled in software, it does take place at the Regional and statewide project-planning level. Surface treatment projects are coordinated with other surface treatment projects, maintenance activities, bridge projects, safety improvement, capacity needs, and local agency projects. Often, thanks to Regional and statewide planning efforts, a CDOT project incorporates multiple assets, multiple needs, and multiple investment sources, thus leveraging the economic advantages of larger, holistic project scopes. This coordination also reduces overall construction delays for roadway users.

5.1.2 Developing treatment recommendations

CDOT's Surface Treatment Program (STP) strives to maintain the quality of the pavement on state highways at the highest level possible by allocating limited resources in a rigorous, data-driven approach. In addition to managing pavement quality, the program directs a small amount of its funds—about 3 percent—toward mitigating safety issues discovered during the project-development process. It is more financially efficient for safety issues to be addressed as part of a current resurfacing project than in a standalone safety project.

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

Table 10: Pavement Work Types by Cost and Benefit

Work Type	Cost Per Lane Mile	Benefit in Drivability Life[13]
Chip Seal	$52,800	0 to 10 years
Ultra-thin Overlay	$140,800	0 to 14 years
Preventive Maintenance	$49,280	4 to 5 years
Minor Rehabilitation	$246,400	15 to 18 years
Major Rehabilitation	$422,400	20 to 23 years
Reconstruction	$992,640	25 years

Source: CDOT

segment, it identifies potential treatment options for that segment based on distresses (smoothness, rutting, and cracking) and overall condition (Drivability Life) ratings.[14]

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 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.

At the project level, even more in-depth analysis is performed. This includes pavement history research, field visits, traffic-data review, and other site-specific analysis that is used to inform the final pavement treatment and project approach. When pavement-material construction costs are estimated to exceed $3 million, a detailed Life-Cycle Cost Analysis (LCCA) for specific treatment options is mandatory. While the pavement-management software

[13] *Benefit refers to the years of Drivability Life remaining after a treatment is performed.*

[14] *CDOT's pavement management software is based on the Department's internal Drivability Life metric. For the purpose of reporting to FHWA, the Department also is developing a model based on National Performance Metrics for pavement, which rates pavements as Good, Fair and Poor.*

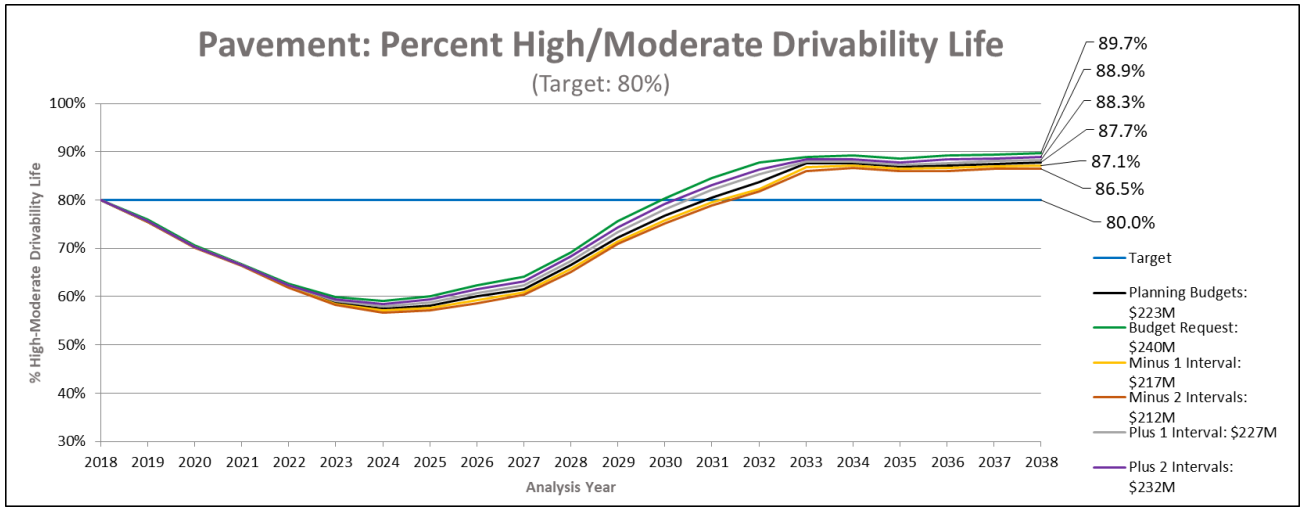
identifies cost-effective treatment categories given site conditions and predicted deterioration, the project-level LCCA compares specific treatment options against each other with detailed site conditions, including information from subsurface investigation. Detailed information on CDOT's LCCA process can be found in CDOT's P*avement Design Manual*.

LCCA can also be used for project and strategic predictive capabilities. CDOT evaluates road surfaces for their Average Annual Daily Traffic and Drivability Life and then compares whether it would be more cost effective to have frequent short-term minor maintenance (e.g., sealing, surface treatments) to maintain the road surface, or wait for long-term major maintenance needs (e.g., major rehabilitation). Determining the ultimate strategy for the road surface would also take into account overall CDOT pavement budgets and maintenance work schedules.

5.1.3 Developing Budget Recommendations

CDOT's also informs its overall pavement budget with life-cycle considerations. The Department at its annual budget-setting workshop weighs investment scenarios at a network level that incorporate recommended life-cycle investment strategies (i.e., a series of treatments) for each asset. The Department develops a scenario based on its current planning budget, as well as scenarios based on higher and lower budgets, to understand return on investment. For example, the performance analysis below shows that the planning budget of $223 million per year results in 88 percent of pavement having high or moderate Drivability Life in 20 years, while a budget of $240 million per year achieves nearly 90 percent high or moderate Drivability Life.

Figure 12: Pavement Investment Scenarios[15]



[15] *Budgets shown are for CDOT's Surface Treatment asset program only. They do not include the Roadway Surface Maintenance Program Area.*

5.2 Bridges Life-Cycle Planning

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

5.2.1 Life-cycle planning strategies

Preserve "Good" and "Fair" Bridges

Maintenance activities can extend the time a bridge remains in its current condition. CDOT's Maintenance Sections perform a variety of preventive maintenance procedures on bridges. To achieve maximum benefit, these procedures focus predominantly, but not exclusively, on structures in Good condition.

An example of preventive procedures is bridge rinsing. Rinsing bridges removes debris that collects on bearing seats from leaking joints. Rinsing also decreases the concentration of salts that remain on decks and cause deterioration. Other examples of preventive maintenance include sealing or resealing concrete in splash zones; replacing, or eliminating leaking joints; sealing or resealing concrete decks; removing debris on bearing seats; and painting or otherwise protecting steel.

The cost and effort for rinsing and similar maintenance activities are lower for Good bridges than for Fair and Poor structures. Such work does not necessarily dramatically improve condition (e.g., from Fair to Good). Instead, these preventive maintenance activities lengthen the time a bridge remains in its current condition compared to untouched structures.

In addition to performing preventive maintenance on Good and Fair bridges, CDOT's Staff Bridge unit focuses rehabilitations on these structures. Examples of rehabilitation activities are deck replacements and repairs, deck protection with application of a membrane, scour remediation, and bridge joint replacement. The main example of rehabilitation for culverts[16] is slip lining. As with preventive maintenance, rehabilitation lengthens the time a structure remains in Fair or Good condition.

Improve the Condition of "Poor" Bridges

CDOT improves the condition of bridges in "Poor" condition primarily through the Colorado Bridge Enterprise, a government-owned business created in 2009. The CBE is legally constrained to perform work on Poor-rated structures. The enterprise has successfully reduced the Department's percentage of Poor bridges primarily through replacements. Since inception, the enterprise has completed projects on 145 structures.

The ownership of the assets is accomplished by resolution approved by the CBE Board of Directors, and CBE becomes responsible for inspection, maintenance, and repair of these assets. Currently, there are 114 CBE-owned assets; 45 of those are non-NHS, while 69 are on NHS. Of this 114 total bridges, 96 were replaced by CBE and 18 were rehabilitated.

[16] *Large culverts are included in CDOT's bridge ("major structures") asset program.*

5.2.2 Developing Treatment Recommendations

CDOT's strategy is not to treat all deteriorating bridges with replacements, which require more cost and effort than other bridge treatments. Instead, the Department's asset management strategies accommodate limited levels of funding and the appropriate effort level for bridges in all conditions. A summary of the Department's strategies for addressing major structures is shown below.

Table 11: Bridge Condition Matrix

Condition	Strategy	Work Unit	Cost	Level of Effort	ROI	Examples
Good	Preservation	Maintenance Sections	Lowest	Lowest	Highest	Bridge rinsing, concrete sealing
Fair	Preservation	Staff Bridge	Medium	Low	High	Deck repairs, deck sealing, joint replacements
Poor	Improvement	Bridge Enterprise	High	High	Low	Bridge and culvert replacements

Estimated annualized costs for appropriate life-cycle treatment on CDOT's bridges far outweigh anticipated budgets for CDOT's Staff Bridge program. This makes it critical that every dollar spent maximizes the value CDOT achieves in improving its inventory.

Historically, CDOT did not use network-level life-cycle planning to decide on the type of bridge to build or on preventive actions. Instead, CDOT selected the type of structure to build based on lowest-first cost, corridor requirements, or environmental regulations. However, CDOT addressed life-cycle planning indirectly by incorporating design features or activities that extended service life (e.g., requiring waterproofing membrane under asphalt on bridge decks or sealing bridge decks at the time of original construction).

Life-cycle planning 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.

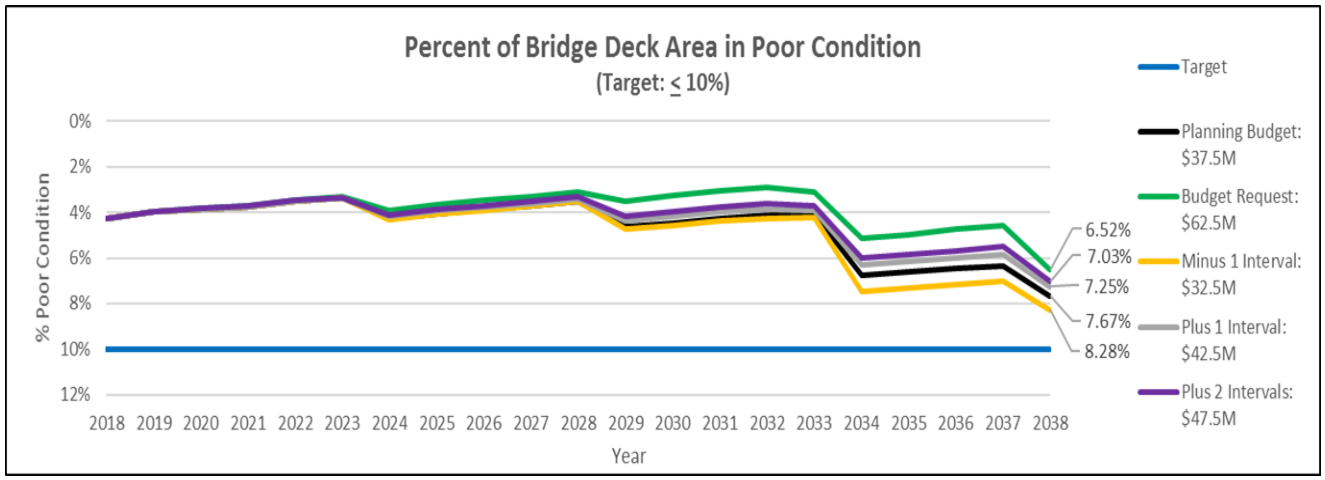
Along with developing the emerging bridge model, CDOT plans to update its assumption in its existing analysis in its AIMS model, including unit costs, deterioration rates and more. The current AIMS analysis uses deterioration rates specific to each structure and component (e.g., deck, superstructure, substructure, etc.).

Along with extensive communication between Regions and CDOT's staff bridge unit, analyses from the new Bridge model and AIMS helps identify future bridge candidates for replacement, repair, rehabilitation and preservation based on an optimal investment strategy.

Developing Budget Recommendations

As with its pavements, CDOT informs its overall bridge budgets with life-cycle considerations. The Department at its budget-setting workshop weighs investment scenarios at a network level that incorporate recommended life-cycle investment strategies (i.e., a series of treatments) for each asset. The Department develops a scenario based on its current planning budget, as well as scenarios based on higher and lower budgets, to understand return on investment. For example, the performance analysis below shows that a planning budget of $37.5 million per year for preventive maintenance (in addition to Bridge Enterprise funding) would lead to about 7.7 percent of bridges in poor condition in the year 2038, while a budget of $62.5 million per year would shrink that percentage to 6.5 percent.

Figure 13: Bridge Investment Scenarios[17]



[17] *The graphic demonstrates the effect of varying budget levels for CDOT's bridge preventive maintenance program only. Assumptions for Bridge Enterprise funding are the same for each scenario and are not shown in the legend.*

6.0 Financial Plan

This section describes CDOT's financial plan for fiscal years 2020-30, including the process for asset-management resource assignment and budget allocation, estimates of revenue and costs for meeting performance targets, and more.

Per federal requirements[18], the financial plan includes:

- *Anticipated sources of funding.*
- *Funding expected to address the costs of future work types, by fiscal year.*
- *Estimated cost of future work to implement investment strategies contained in this plan, by state fiscal year and by work type.*
- *The value of CDOT's National Highway System (NHS) pavement and bridges and the annual investment needed to maintain value.*

6.1 Sources of Funding

CDOT's total revenue for FY 2020 is about $1.96 billion. (See Table 12.) 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.

CDOT's largest source of revenue in a typical year is the Highway Users Tax Fund (HUTF). (In fiscal year 2020, state General Fund Transfers are more than HUTF funds, however.) HUTF is a constitutionally dedicated revenue source comprised of a combination of motor fuel taxes, motor vehicle registration fees, and other revenue.

Federal-aid highway funding constitutes the second largest category of revenues for the state transportation system. These funds are authorized by Congress from the Highway Trust Fund (HTF) to assist states in providing for construction, reconstruction, and improvement of highways and bridges on eligible Federal-aid highway routes and for other special purpose programs and projects. Tax revenues directed to the HTF are derived from excise taxes on motor fuel, alternative fuels taxes, and truck-related taxes on truck tires, sales of trucks and trailers, and heavy vehicle use.

The major sources of revenue for HUTF and HTF are the state and federal motor fuel taxes, which are based on the volume of gallons sold, rather than on the price per gallon. Thus, growth in gas tax receipts only comes from increases in the amount of fuel sold and not from increases in the price per gallon. This poses a challenge for revenue collection as vehicles become increasingly fuel efficient, and the declining consumption of gasoline does not match increasing total road usage. In the state of Colorado, the current tax rate on gasoline is 22 cents per gallon, and the current rate on diesel fuel is 20.5 cents per gallon. The excise tax rate was last adjusted by the

[18] *See 23 CFR 515.7*

General Assembly in 1992, and any future increases in the rate are subject to voter approval. Congress last adjusted the federal gasoline tax in 1993 to its current 18.4 cents per gallon rate.

Table 12: Fiscal Year 2020 CDOT Budget: Revenue Sources (in millions)

Summary of CDOT Revenue Estimate	
Funding Category	**Estimate FY 2019-20**
Highway User Tax Fund (HUTF) Revenue	586,004,881
Miscellaneous State Highway Fund	28,119,000
Safety Education Funding	11,395,000
State Local Match (Safe Routes to Schools)	625,000
General Fund Transfers	678,000,000
Transit Revenue	48,092,469
Aeronautics Revenue	33,000,000
State Infrastructure Bank Interest Income	507,000
Federal Highway Revenue - The Highway Trust Fund (Highway Account)	573,065,323
Colorado Department of Transportation - Total Revenue	**1,958,808,673**

Source: CDOT FY 2019-20 Final Budget Allocation Plan

Vehicle registration fees from Colorado's Funding Advancement for Surface Transportation and Economic Recovery (FASTER) Act, or Senate Bill 09-108, have helped improve bridge condition and fund safety-focused asset management projects. The bill generates about $200 million per year for CDOT's transportation projects across the state. FASTER legislation also created two state-owned enterprises that are critical to asset management at CDOT: The Colorado Bridge Enterprise and the High-Performance Transportation Enterprise.

- The Colorado Bridge Enterprise repairs, rehabilitates, and replaces bridges in "Poor" condition. The Enterprise 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, averaging roughly $100 million per year. Because it was constituted as a Government-owned business, the Enterprise issues revenue bonds to accelerate replacements or improvements of poor bridges.

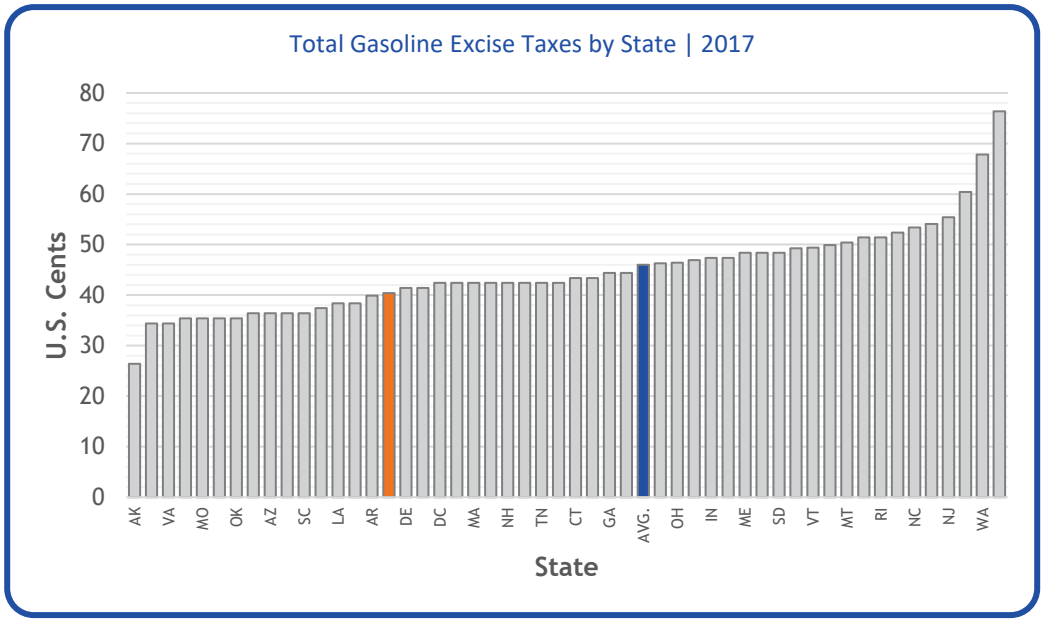
- The High Performance Transportation Enterprise, meanwhile, replaced the Colorado Tolling Enterprise, and leverages innovative ways of financing transportation, such as public-private partnerships, the operation of concession agreements, and fee-based projects.

Colorado has passed several bills in the past few year to provide significant, additional funding to CDOT. For example, SB 18-001, passed by the Colorado General Assembly in May 2018, includes a variety of possible funding scenarios dependent upon different external factors. The summary below begins with the immediate policy and funding impacts with subsequent paragraphs describing possible future scenarios described in legislation. General

Fund Transfers IN FY20, SB 18-001 transfers are expected to provide $150 million to state and local transportation projects statewide. This is divided 70 percent to the state, 15 percent to local governments and 15 percent to a new Multimodal Options Fund (MMOF). The local money is split evenly between cities and counties and will be distributed via the local government Highway Users Tax Fund (HUTF) distribution formula. The Multimodal Options Fund is administered by CDOT, with 85 percent for local multimodal projects and 15 percent for statewide projects. The multimodal funds may be used for transit or bike/pedestrian projects, operating expenses or studies. In FY19, SB 18-001 provided a total of $490 million, also divided 70 percent to the state, 15 percent to local governments, and 15 percent to the MMOF.

Senate Bill (SB) 17-267 SB 18-001 protects the first of four possible issuances of Certificates of Participation (COPs) under SB 17- 267. The first issuance of $380 million in par value was made in FY 2018-19 and resulted in proceeds to CDOT of approximately $425 million. A second issuance of $500 million in par value can occur as early as July 1, 2019, subject to provisions included in SB 18-001, or changes in law.

Figure 14: Gas Taxes by State



Colorado has one of the lowest gas taxes in the nation. Federal and Colorado motor fuel excise taxes have not increased since the early 1990s.
Source: Federal Highway Administration

6.2 Process for Estimating Funds Available for Asset Management

This section describes important budget processes relevant to estimating asset management budgets at CDOT. They include:

- **The Annual Planning Budget Process—**This process is used to determine available funds for each asset program for future fiscal years. While these budgets are for planning purposes only, they often influence actual budgets approved at a later date.
- **Program Distribution—**This is the process used by CDOT during the Statewide Planning process to describe the investment strategy and potential allocations between program areas over the long term. The most recent Program Distribution estimate spanned 25 years. The process formerly was referred to as "Resource Allocation."

6.2.1 Annual Planning Budget Process

Establishing planning budgets for individual asset programs is a core component of CDOT's asset management process. Projection of funding availability is required by the Regions years in advance due to design timeframes needed for successful program and project delivery. The Department's method for arriving at planning budgets is described below:

- Every year, the TAM Oversight Committee establishes an overall budget for asset management, which in recent years has been about $755 million. The committee includes the Executive Director, Deputy Director Chief Engineer, Chief Financial Officer, a Regional Transportation Director and various Division Directors.
- CDOT organizes its annual Asset Management Budget-Setting workshop, which more than 30 staff members typically attend. Invited staff include members of senior management, Regional Transportation Directors, asset managers, and additional Region and headquarters staff. This group develops a staff budget recommendation for the fourth year in CDOT's rolling four-year program of asset management projects.
- Asset managers use forecasts from CDOT's Asset Investment Management System (AIMS) to present their asset's anticipated future performance versus investment levels, and make the case for funding their program to workshop attendees. Staff ensures that each asset manager is using the same assumptions for long-term performance curves and budget scenarios (e.g., inflation rates, discount rates, and revenue growth assumptions).
- Along with the performance curves, workshop attendees review supporting information including the asset's budget request, historical funding, and performance targets from CDOT's Policy Directive 14. Asset managers also present available information on past projects and what can be achieved with additional funding.
- Consensus is achieved among workshop participants in distributing the limited pool of asset management funds—typically after several rounds of voting—as participants share why they voted the way they did, and asset managers provide comments.

- Following the workshop, the TAM Oversight Committee has the ability to approve the staff budget recommendation or to make modifications. The planning budget recommendation is later presented before the Transportation Commission for approval, and the distributions become CDOT's official planning budgets.
- Planning budgets typically heavily influence actual annual budgets, which are approved separately by the Commission at a later date.

CDOT's total budget for asset management activities typically reaches about half of annual revenues in a typical year. The total asset management budget has remained relatively stable in recent years, ranging from $743 million for FY2014 to $755 million for FY2019. CDOT has discretion about how to allocate available funds across different assets and types of needs, within the confines of funding eligibility restrictions. For instance, the National Highway Performance Program (NHPP) represents the largest category of federal revenues for Colorado and the majority of funding available is for preservation of the state's highway and bridge assets. Portions of the Surface Transportation Block Grant Program (STBGP) also fall within the statewide discretion of CDOT and are therefore considered eligible for asset management spending.

The largest recipient of funds is Maintenance, which has received more than $260 million per year in recent years. After Maintenance, Pavement and Bridge have received the most funding among the assets. Of the total funds provided to asset management, over 80 percent is typically provided to these "big three" asset areas. The remainder is distributed across the Fleet (Road Equipment), ITS, Signals, Culverts, Geohazards (Rockfall Mitigation), Buildings, Tunnels, Walls, and Rest Areas asset programs.

6.3 Cost to Achieve State of Good Repair for Pavement

CDOT in 2018 met its fiscally constrained target in Policy Directive 14 for pavement condition, which is for 80 percent of state highway system pavement to have High or Moderate Drivability Life.

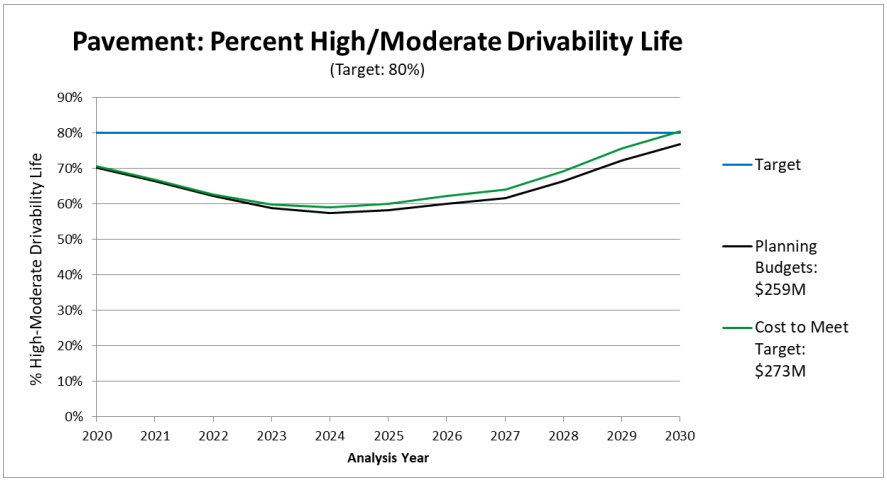
Under 2018 model projections, CDOT forecasts it must invest an *average* of $273 million per year[19] from 2020-30 to achieve the 80 percent target. Conditions would dip to a low of 59 percent High/Moderate Drivability Life in fiscal year 2024, but return to 80 percent by fiscal year 2030. Against average projected budgets for the Surface Treatment program and roadway-surface maintenance for the next 10 years—about $259 million per year—there is a deficit of about $14 million per year.

This analysis represents the cost for achieving CDOT's target for its entire system. However, maintaining this inventory in satisfactory condition also contributes significantly to the health of the National Highway System, as CDOT's system includes 87 percent of the NHS, by lane miles. Municipalities and counties own 13 percent. CDOT also maintains 9,500 lane miles of pavement not included in the NHS.

The Department is developing analyses to forecast costs and conditions for Interstates and the rest of the NHS according to National Performance Measures for pavement (i.e., Good, Fair and Poor). Projections under these analyses remain a work in progress, and the Department is verifying/refining deterioration rates for distresses used in the preliminary model analyses, as well as other inputs. Preliminary estimates based on the initial analyses show the percentage of "Poor" pavement on the Interstate continuing to increase through 2030 when using current Interstate investment strategies/funding levels. This projected increase in "Poor" Interstate condition may prompt the Department to reconsider its strategic investments in pavements.

While CDOT has not finalized analyses for National Performance Measures, there is considerable overlap in the distresses used by the Department's Drivability Life metric and the national Good, Fair, Poor metrics. Despite using similar base data, however, calculations behind the two metrics differ considerably. For more on the relationship between Drivability Life and Good, Fair and Poor, see Section 3 of this plan.

Figure 15: Pavement Condition Forecast, 2020-30



[19] *This estimate includes funding for CDOT's pavement asset-management program and for its Roadway Surface Maintenance Program Area.*

Table 13: Cost to Achieve Pavement State of Good Repair by 2030, by Work Type

Work Type	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Maintenance	$ 37.90	$ 35.30	$ 36.30	$ 33.90	$ 34.90	$ 34.20	$ 35.20	$ 34.50	$ 35.50	$ 36.60	$ 37.70
Preservation	$ 27.40	$ 20.70	$ 25.10	$ 36.30	$ 53.30	$ 55.70	$ 59.00	$ 18.50	$ 173.80	$201.80	$ 190.30
Rehabilitation	$ 195.80	$ 202.60	$ 214.90	$ 203.70	$186.70	$ 184.30	$181.00	$221.50	$ 66.20	$ 38.20	$ 45.50
Reconstruction	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 4.20
Total	$ 261.10	$ 258.60	$ 276.30	$ 273.90	$274.90	$ 274.20	$275.20	$274.50	$ 275.50	$276.60	$ 277.70

The table above shows the cost of meeting CDOT's target for pavement condition for the state highway system using the Department's Drivability Life metric. See Table 16 for expected budgets by work type over the same period.

Cost to Achieve State of Good Repair for Bridges

CDOT in recent years has achieved its primary fiscally constrained target in Policy Directive 14 for bridge condition, which is for no more than 10 percent of deck area on the state highway system to be in Poor (also called "structurally deficient") condition. About 4 percent of deck area was in Poor condition in 2018. CDOT's definition of Poor is synonymous with the definition of Poor in National Performance Measures.

The Department forecasts that CDOT's investment levels in bridge condition from 2020-30—about $117 million per year on average when considering bridge preventive maintenance program, the Bridge Enterprise and the Maintenance Program Area for structure maintenance—will be sufficient to continue achieving the topline bridge target through 2030. (See Figure 19 for this trend analyses.)

CDOT owns and maintains 3,460 bridges. Maintaining this inventory in satisfactory condition contributes significantly to the health of the National Highway System, as CDOT owns 88 percent of bridges on the NHS, while about 12 percent of NHS bridges are locally owned.

While current budgets may be sufficient to maintain CDOT's overall target for bridges, they fall short of meeting all bridge needs. For example, the percentage of the Department's bridge inventory in Fair condition is expected to grow, while the percentage of Good is expected to decrease under expected funding levels. This trend will increase CDOT's costs in the long term. In addition, CDOT estimates that achieving the top three risk-management goals of its bridge preventive maintenance program—sealing bridge decks, replacing joints and mitigating scour—would cost about $67 million per year for the next 10 years, versus a current budget of about $37 million per year for the program.

The Department is developing analyses to forecast costs and conditions for the National Highway System according to National Performance Measures for pavement (i.e., Good, Fair and Poor). CDOT's current model analyzes the entire CDOT system—not the just CDOT's portion of the NHS, and not NHS structures owned by other agencies. Additionally, the Department is exploring analyses that can optimize based on both Good and Poor condition. CDOT's current model optimizes based on Poor condition alone. These analyses remain works in progress.

Figure 16: Bridge Condition Forecast, 2020-30

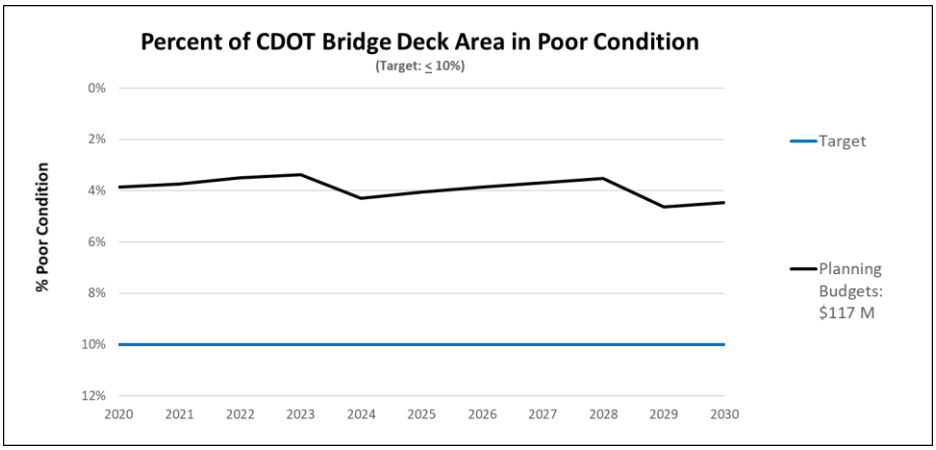


Table 14: Cost to Achieve Bridge State of Good Repair by 2030, by Work Type

Work Type	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Preservation	$ 21.7	$ 19.4	$ 25.2	$ 26.5	$ 26.4	$ 26.2	$ 26.1	$ 26.0	$ 25.9	$ 25.7	$ 25.6
Rehabilitation	$ 13.6	$ 8.6	$ 23.0	$ 13.1	$ 19.4	$ 19.6	$ 19.1	$ 19.0	$ 19.6	$ 19.7	$ 20.0
Reconstruction	$ 43.7	$ 34.8	$ 84.6	$ 45.0	$ 70.3	$ 71.3	$ 69.4	$ 68.8	$ 71.2	$ 71.8	$ 72.8
Maintenance	$ 10.0	$ 9.2	$ 9.2	$ 9.3	$ 9.5	$ 9.9	$ 9.9	$ 10.2	$ 10.5	$ 10.6	$ 10.8
Total	$ 89.0	$ 72.0	$ 142.0	$ 93.9	$ 125.6	$ 127.0	$ 124.5	$ 124.0	$ 127.2	$ 127.8	$ 129.2

The table above shows CDOT's planning budgets for bridge condition through 2030, which are sufficient to achieve the Department's target for the percent of bridge deck area in Poor condition. These funding levels are not sufficient to meet all the Department's strategic goals for bridges, including risk-management goals in the bridge preventive maintenance program.

6.4 Asset Valuation

Understanding the value of assets is a critical step in preserving them. To that end, CDOT has taken steps to estimate the value of the agency's NHS pavement and bridges. CDOT adopted a data-driven methodology that accounts for asset depreciation over time, going beyond current replacement value (CRV) 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. This approach compares the remaining life of the asset to its initial service life.

Table 16 shows the breakdown of current and replacement values by asset class. As of 2018, CDOT's NHS pavement and bridge assets amount to roughly $36.6 billion in current value (cv) and $41.1 billion in replacement value (rv).

Pavement is the largest asset class at CDOT. The value of the agency's NHS pavement in 2018 is estimated to be $10.7 billion against a replacement value of $13.6 billion, for a percentage remaining of 79 percent. The Department estimates the average annual cost to maintain this value is about $77 million per year from 2019-30. Readers should note that maintaining value is not synonymous with meeting all of the Department's strategic goals for an asset. For example, the pavement network's overall value may be maintained even as stretches of critical pavement fall below acceptable condition.

Bridges are the second largest asset class at CDOT. The value of the agency's NHS bridges in 2018 is estimated to be $25.9 billion against a replacement value of $27.5 billion, for a percentage remaining of 94 percent. The Department estimates the average annual cost to maintain this value is about $43 million per year from 2019-30[20]. Readers should note that maintaining value is not synonymous with meeting all of the Department's strategic goals for an asset. For example, the bridge network's overall value could be maintained even as certain bridges or corridors fall below acceptable condition, or as risk-management goals are not met.

Table 15: Current and Replacement Values for CDOT's NHS Pavement and Bridges

Asset Class	2018 Value	Replacement Value	Percentage Remaining[1]
CDOT NHS Pavement	$10.7 billion	$13.6 billion	79%
CDOT NHS Bridges[21]	$25.9 billion	$27.5 billion	94%

[1] *Percentage remaining is calculated as a simple quotient of current value divided by replacement value.*

[20] *This estimate does not include the cost to maintain Bridge Enterprise bridges on the NHS, which account for about 3 percent of the state-owned structures on the NHS. The estimate also does not include the cost of inspections, nor the cost of meeting certain risk-management goals for CDOT, such as reducing the percentage of bridges that are scour critical.*

[21] *CDOT NHS bridges include large culverts.*

7.0 Investment Strategies

This section illustrates the investment strategies CDOT plans to leverage to approach system-wide asset condition goals while minimizing life-cycle costs. The section builds off the life-cycle planning approaches, budget-setting process and anticipated budgets presented in previous chapters to focus on the Department's anticipated investments in pavement and bridge assets, by work types.

7.1 CDOT Bridge and Pavement Budgets by Work Type

Table 16 below shows anticipated budgets for CDOT's pavement and bridge assets from 2020-30 by work type.

Table 16: CDOT Asset Management, Anticipated Budgets by Work Type (in millions)[22]

	2019-20	2020-21	2021-22	2022-23	2023-24	2024-25	2025-26	2026-27	2027-28	2028-29	2029-30
Pavement	**$259.9**	**$258.5**	**$259.6**	**$257.2**	**$258.2**	**$257.5**	**$258.5**	**$257.8**	**$258.8**	**$259.9**	**$261.0**
Maintenance	$37.9	$35.3	$36.3	$33.9	$34.9	$34.2	$35.2	$34.5	$35.5	$36.6	$37.7
Preservation	$27.6	$20.7	$24.5	$32.2	$50.6	$55.1	$54.4	$19.7	$166.8	$180.6	$180.7
Rehabilitation	$194.4	$202.5	$198.8	$191.1	$172.7	$168.3	$168.9	$203.6	$56.5	$42.7	$42.6
Reconstruction	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Bridges	**$89.0**	**$72.0**	**$142.0**	**$93.9**	**$125.6**	**$127.0**	**$124.5**	**$124.0**	**$127.2**	**$127.8**	**$129.2**
Maintenance	$10.0	$9.2	$9.2	$9.3	$9.5	$9.9	$9.9	$10.2	$10.5	$10.6	$10.8
Preservation	$21.7	$19.4	$25.2	$26.5	$26.4	$26.2	$26.1	$26.0	$25.9	$25.7	$25.6
Rehabilitation	$13.6	$8.6	$23.0	$13.1	$19.4	$19.6	$19.1	$19.0	$19.6	$19.7	$20.0
Reconstruction	$43.7	$34.8	$84.6	$45.0	$70.3	$71.3	$69.4	$68.8	$71.2	$71.8	$72.8

7.2 New Construction

In addition to spending asset management funds on the existing transportation system, CDOT finances new construction on the system. In recent years, the Department has lacked the funds to operate a consistent, ongoing program focused on new construction. Instead, the Department funded expansion projects as funds became available.

For fiscal year 2020, the Department anticipates a significant increase in funding, largely from the State of Colorado's General Fund. Due in part to these funds, CDOT expects to spend about $790.7 million in new construction for fiscal year 2020. Of that total, about $118.1 million will be spent on safety-related projects, while

[22] *The amounts for work types represent forecasts extrapolated from planning budgets approved at CDOT's annual budget-setting workshop, work plans, and model recommendations. Total pavement figures combine anticipated budgets for the Roadway Surface Maintenance Program Area (MPA) with anticipated budgets for the Surface Treatment program. Total bridge figures combine anticipated budgets for the Structures Maintenance MPA with anticipated budgets for CDOT's bridge preventive maintenance program and the Bridge Enterprise.*

about $23.1 million will be spent on projects for the National Highway Freight Program. Safety and freight projects are likely to comprise much of CDOT's new construction going forward, as those project types have relatively stable revenue sources.

8.0 Next Steps

CDOT is committed to remaining at the forefront of asset-management practices and technologies. This commitment will require the Department to leverage everything from mature modeling systems to sensors in emerging "vehicle-to-everything" infrastructure to maintain assets in the best condition possible for the least practicable cost.

The Department in early 2019 held a series of workshops with asset managers to identify ways to enhance asset management at the agency and program levels. The following themes emerged:

- Improving data collection, integration and analysis.
- Refining business processes, including risk processes and project selection and prioritization.
- Strengthening cross-asset collaboration.
- Managing talent for the future.

8.1 Improving Data Collection, Integration and Analysis

CDOT identified several agency gaps related to data. The Department must make strides in the automation of data collection, data standardization, data integration, aligning data with organizational needs, and finding innovations through "Big-Data" analysis and business intelligence. CDOTs Chief Data Office, which was designed to help the Department solve data challenges, is a valued partner with CDOT's asset programs in these efforts.

- CDOT can benefit from **standardizing data** in areas such as asset inventories and condition assessments. Collecting data consistently across asset types and Regions will improve data integrity and cross-asset analytics.
- CDOT should better **align data with organizational needs.** The Department must align its data-collection activities, such as collecting asset condition information, to achieve economies of scale. The Department also should identify new data sources to support risk and resilience efforts and more sophisticated benefit-cost analysis, including as it relates to Multi-Objective Decision Analysis[23].
- CDOT should seek opportunities to **automate data** by leveraging the proliferation of sensors, satellite imagery and other imaging technologies to improve asset management. For example, the Department could install sensors on its vehicles to gather data on potholes and loose bridge joints.
- CDOT should continue **improving data integration.** Integrating data means weaving information together to provide better insights for making asset-management decisions, specifically for cross-asset management. This requires investment in high-level systems architecture to provide better integration among all data, including GIS, asset inventory, condition, work planning, and financial management. Data integration also can strengthen data standardization and automation.
- CDOT should expand **analysis of rich-data sources**, such as maintenance work orders, real-time operations data, and connected- and automated-vehicle information, to inform how assets are managed. Business intelligence

[23] *See Section 8.2 in the following pages for a description of MODA.*

solutions can leverage this information to enhance asset-maintenance planning and inform risk and resilience management.

Below is a sampling of current projects already underway at CDOT to improve data collection, alignment, automation, integration and analysis.

- **Enterprise Light Detection and Ranging (LiDAR) Data Collection.** CDOT recently completed an enterprise-wide LiDAR strategic plan in preparation for a statewide-data collection effort. LiDAR is an imaging technology that collects geospatial data by measuring the distance to a target by illuminating the target with a laser light. LiDAR can be used to collect asset inventory and condition data, among other information. Multiple stakeholders, including asset managers, surveyors, designers, environmental planners, and maintenance staff, participated in workshops to document needs, requirements, and opportunities.
- **Geospatial platform improvements with Esri System of Engagement (SoE).** CDOT has developed a partnership with Esri, a mapping technology company, under which software licenses, geospatial services and data assets can be leveraged to quickly produce viewers and analysis tools. The partnership will enable CDOT to create audience-specific applications and dashboards to visualize, analyze and capture spatially relevant data. Examples include the Statewide Transportation Improvement Plan (STIP) Project Viewer, Nighttime Maintenance Inspection App, and the Maintenance Asset Inventory Viewer.
- **OnTrack.** OnTrack is an initiative from CDOT's Program Management Office to modernize and aggregate CDOT's construction management processes, starting with pre-construction and project management. The initiative will integrate CDOT's financial information in SAP software and SiteManager payment information for more accurate drawdowns and project estimates.
- **System for Inspection and Management of Structures (SIMSA).** SIMSA is a new bridge management and inspection system being developed by CDOT's bridge preventive maintenance program. Compared to current capabilities, the system will enable more advanced and immediate querying, data review, and report generation. These features will enable CDOT to better understand, track, and strategically implement life-cycle planning principles. The effort leverages Cambridge Systematics' TransAM software.
- **Asset-Management System Enhancements.** CDOT is updating asset-management tools including its Asset Investment Management System (AIMS), which models asset condition and helps determine appropriate asset treatments. The Department is working with its AIMS vendor to add functionality including forecasting based on new National Performance Measures, such as those for NHS pavements and bridges. The Department also plans to integrate Multi-Objective Decision Analysis[24] capabilities into AIMS. This will improve the system's ability to recommend optimal funding and treatments across assets while weighing costs and benefits across multiple goal areas.

[24] *See Section 8.2 on the following page for a description of MODA.*

8.2 Refining Business Processes

In addition to data refinements, CDOT has identified several ways current business processes can be refined to improve asset management. These include:

- **Multi-Objective Decision Analysis**—CDOT is exploring ways to improve project selection and prioritization, such as through Multi-Objective Decision Analysis (MODA). MODA is a process for informing investment decisions through analysis and scoring of multiple criteria to meet complex department goals. CDOT is refining MODA-related criteria to assess how investment in asset treatments could affect safety, mobility, economic vitality, risk and other goal areas. Once developed, the Department will explore integrating these processes into its asset model to help select and prioritize projects.
- **Risk Management**—This plan introduces a process for integrating risk and resilience into asset-management investment decisions. *(See Section 2 for a full description of this developing process)*. The Department will continue to develop this process, including refining roles and responsibilities.

  And starting with this plan, CDOT's risk register *(See Appendix 2)* groups threats into social, economic and environmental categories. The emphasis on these categories will encourage CDOT to expand the factors it considers in pursuing its policy of building and maintaining a more resilient transportation system.

8.3 Improving Cross-Asset Collaboration

CDOT's asset-management program comprises 12 diverse assets classes—from pavement to culverts to rest areas—offering opportunity for robust cross-asset collaboration. Such collaboration can serve to enhance processes including:

- **Modeling and project prioritization.** CDOT's Asset Investment Management System—the Department's asset modeling tool—has historically existed on just a few desktop systems within the Department, which limited access to a few users. Moreover, the processing power required to run analyses meant each analysis required significant time to run. The Department in 2018 invested in a faster, cloud-based version of the system, which is scheduled to be fully deployed in 2019. As a result, all CDOT asset managers will soon have access to the system, offering opportunities to share knowledge on model development and various system functions, including project-selection analyses, data-visualization tools, and more.
- **Target-setting and performance measurement.** CDOT has included in this plan internal and federally required targets for pavement and bridges. All managers of CDOT's 12 asset programs develop targets to satisfy state and internal Department requirements for document such as the CDOT Performance Plan. Asset managers, in coordination with the Department's Performance and Asset Management Branch, develop targets by studying projected funding, historical performance, regression analyses and more. What's more, CDOT regularly reviews progress on target achievement in monthly performance meetings and other venues. This emphasis on target setting, performance monitoring and reporting is strengthening the asset-management program by creating an informal community of practice for performance measurement within CDOT.

8.4 Managing Talent for the Future

Employees need the right tools and training to effectively implement the asset-management processes described in this plan, including developing performance metrics and targets, estimating whole life-cycle costs, managing risks, and prioritizing projects to achieve multiple goal areas.

In addition to hiring the right people, the Department recognizes the need for more comprehensive training to support CDOT's robust asset management program. While expertise already exists throughout the Department, training across all programs can be improved so that knowledge is applied consistently. For example, choosing asset-management projects based on their ability to meet multiple goal areas, such as through MODA techniques, will require both headquarters- and Region-based asset managers to understand sophisticated project-scoring methodologies. As previously mentioned, CDOT also is expanding access to its AIMS asset-modeling tool to all asset groups by moving to a cloud-based portal and will continue to provide associated training. The Department's Asset Management Working Committee will continue engaging with a broad mix of Department staff to align these and other tools and training with CDOT's asset management needs.

Appendix 1: CDOT Criticality Map

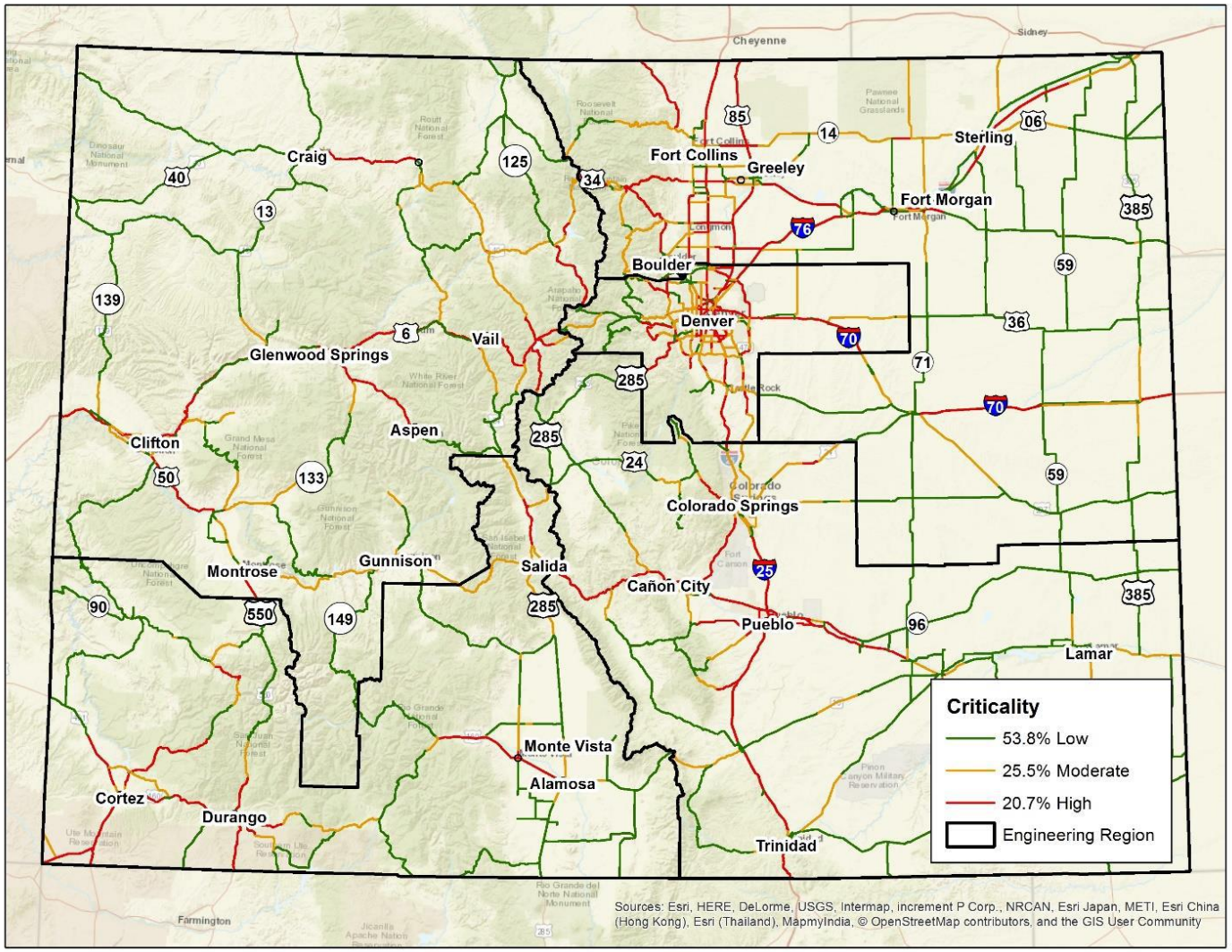


Figure 17: CDOT Asset Criticality Map for System Resilience

Appendix 2: CDOT Risk Register

					DIRECT CONSEQUENCES					OTHER CONSIDERATIONS				
	Risk Level	Asset Class	Threat	Likelihood of Threat/Occurrence	Safety	Mobility	Asset Damage	Other Financial Impact	Approximate Dollar Value of All Consequences	Funding	Insurance	Regulatory	Political	Reputation
Discussion prompt	Is the risk seen at an Agency, Programmatic, or Project level? Can it be viewed at multiple levels?	Is the risk specific to a single asset class, multiple asset classes, or all asset classes?	Description of threat or occurrence	What is the likelihood, on a scale 1-5, of unwanted threat occurring	Given the event occurs, on a scale of 1-5, what would be the impact to safety?	Given the event occurs, on a scale of 1-5, what would be the impacts to mobility?	Given the event occurs, on a scale of 1-5, what would be the level of asset damage?	Given the event occurs, on a scale of 1-5, what would be the level of other financial impacts?	*The total dollar value of consequences using the set consequence costs*	Will the event and consequences have an impact on CDOT current or future funding? Require additional unplanned funding?	Will event and consequences be covered under current CDOT insurance coverage? Impact future coverage?	Are there regulations relevant to CDOT for the prevention, impacts and/or response to this event or consequences?	Will the event have a political impact on CDOT? Require a political response?	Will the event impact the reputation of CDOT with relevant internal/external stakeholders?
Social	Agency	All	Lack of flexibility to redirect funds between programs.	4	1	1	1	1	$ 200,000.00	x				
	Agency	All	Investment does not result in forecasted performance over time	5	1	1	1	1	$ 200,000.00	x				
	Agency	All	MPO - FHWA infrastructure condition (pavement and bridge) target setting. Limited control over MPO investments, including their project selection and prioritization.	4	1	1	1	1	$ 200,000.00				x	x
	Agency	All	Funding and revenue variations/uncertainties (positive)	5	1	1	1	3	$ 1,400,000.00	x				
	Agency	All	Funding and revenue variations/uncertainties (negative)	5	1	1	1	3	$ 1,400,000.00	x				
	Agency	All	Shifting political priorities within CDOT or of external political stakeholders (Legislature, Governor, etc.)	3	1	1	1	1	$ 200,000.00	x			x	x
	Agency	All	Public perception of CDOT's efficient use of funds which could result in redirection of funds	5	1	1	1	1	$ 200,000.00				x	x
	Agency	All	Lack of engagement/communication of planning partners in development of agency initiatives	5	1	1	1	1	$ 200,000.00				x	x
	Programmatic	All	Lack of process development/improvements to support changing agency level initiatives	3	1	1	1	1	$ 200,000.00					
	Programmatic	All	Inability to recruit, retain, and train staff during a period of evolving organization need	5	1	1	1	1	$ 200,000.00					
	Agency	All	Man-made malicious acts or activity against CDOT assets or operations (for example: sabotage or terrorism)	4	3	2	2	1	$ 1,900,000.00	x	x			
	Programmatic	All	Subsurface utilities impacts CDOT ROW and infrastructure, especially on Interstates (SB 18-167)	5	1	1	1	2	$ 450,000.00	x	x	x		
	Programmatic	All	Major projects have cost overruns which impacts CDOT budgets for other activities	5	1	1	1	1	$ 200,000.00	x				
	Programmatic	All	Data management and collection (lack of data or ability to understand data, redundant data collection, that impacts ability of CDOT to document accomplishments)	5	1	1	1	2	$ 450,000.00	x		x		
	Programmatic	All	Unintended scope growth (creep) after the work has started	5	1	1	1	1	$ 200,000.00	x				
Economic	Agency	All	With limited and variable funding CDOT may not be able to meet CDOT PD14 targets in the desired timeframe	5	1	1	1	1	$ 200,000.00	x				
	Agency	All	Not achieving NPM targets for statewide FHWA infrastructure condition (pavement and bridge)	3	1	1	1	5	$ 20,150,000.00	x		x	x	x
	Agency	All	Commodity price volatility	5	1	1	1	1	$ 200,000.00	x				
	Agency	All	Financial collapse of a privately-owned tolled facility, assuming our contract language was not in their business interest or they go bankrupt	2	1	1	1	1	$ 200,000.00	x			x	x
	Agency	All	Constraints within the contracting community (capacity or availability)	4	1	1	1	1	$ 200,000.00				x	x
	Agency	All	Impact to CDOT of insolvency/uncertainty of planning partners and stakeholders	1	1	1	1	1	$ 200,000.00	x				x
	Agency	All	Cybersecurity and unwanted access to CDOT systems, data, or operations	4	1	1	1	1	$ 200,000.00	x	x			x
	Agency	All	Ballot initiative which affect CDOT strategic planning or project pipeline	5	1	1	1	1	$ 200,000.00	x		x	x	x
	Programmatic	All	Lack of focus on maintenance needs and activities with new or increases in CDOT funding	4	2	1	1	1	$ 450,000.00	x				x
	Programmatic	All	New state/federal requirements necessitating additional unplanned resources	3	1	1	1	1	$ 200,000.00	x		x	x	
Environmental	Programmatic	All	Flooding (or any inclement weather threat) (resulting in long term impacts -- damage to assets, requiring replacement)	2	5	5	5	5	$ 80,000,000.00	x	x	x	x	x
	Programmatic	All	Wildfire - >20,000 acres	4	5	5	3	3	$ 42,500,000.00	x	x	x	x	x
	Agency	All	Regional Power Outage	1	2	2	1	1	$ 700,000.00					
	Agency	All	Extreme Regional Weather Threat (hail, lightning, snowstorm, tornados, high-wind	5	4	2	1	1	$ 6,900,000.00					
	Agency	All	Ecological Threat (infestations, invasive species)	2	1	1	1	1	$ 200,000.00	x				
	Agency	All	Biological Threat (public health emergencies, agricultural emergencies)	1	4	1	1	1	$ 6,650,000.00					

CDOT Risk Register Scoring Rubric

Likelihood

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%

Safety

Level	Descriptor	Description	Cost Range for Event	Set Safety Cost for Event
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

Level	Descriptor	Description	Cost Range for Event	Set Mobility Cost for Event
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

Level	Descriptor	Description	Cost Range for Event	Set Asset Damage Cost for Event
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

Level	Descriptor	Description	Cost Range for Event	Set Other Financial Impact Cost for Event
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

Vulnerability

Level	Descriptor	Description
1	Very low	- Established risk management process(es) exist for event - CDOT responses and contingency plans in already place, and are fully tested - Asset engineering design or asset condition ensures full functionality - Previous resilience efforts provide high degree of protection
2	Low	- Established risk management process(es) mostly exist for event - CDOT responses and contingency plans in already place, but with limited testing - Asset engineering design or asset condition ensures mostly full functionality - Previous resilience efforts provide 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 ensures only partial functionality - Previous resilience efforts provide 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 provides little assurance of functionality - Previous resilience efforts provide very low degree of protection
5	Very High	- Established risk management process(es) do not exists 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 protection