CDOT's Risk-Based Asset Management Plan

final

plan

prepared for

Colorado Department of Transportation

prepared by

Cambridge Systematics, Inc.

with

Larry Redd, P.E.

December 9, 2013

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Executive Summary

The Colorado Department of Transportation (CDOT) maintains more than 9,100 miles of highway and about 3,400 bridges. CDOT operates more than 3,300 vehicles to manage roads statewide. Colorado's transportation infrastructure supports both the state's economy and the active lifestyles of residents and visitors. Highways, bridges, rail lines and other infrastructure connect people to activities and businesses to markets.

Increased demand and diminished funding mean that previous approaches to maintaining the transportation system are no longer sufficient. At the same time, citizens are demanding greater accountability in the use of public funds. In response, CDOT is developing more efficient strategies to make funding decisions based on the performance of assets. These strategies will direct funding to the Department's most critical projects. Transportation Asset Management (TAM) represents a new way of doing business at CDOT and will ensure that the Department reaps the greatest possible return on its investments.

CDOT's Executive Director and the Transportation Commission (TC) directed staff to develop the Risk-Based Asset Management Plan (RB AMP) to chronicle the Department's history of asset management and to define a framework for implementation of new asset management strategies. The TC Asset Management Committee set the course for implementation of TAM by setting performance targets for pavement, structures, and maintenance levels of service. In addition, the committee has emphasized the need for data-driven budgetary decisions, including the development of a trade-off tool that recommends appropriate engineering treatments at the lowest life-cycle cost on a statewide basis.

The purpose of the Plan is to provide a framework for CDOT staff to carry out the direction of the TC and the Executive Director. It defines specific TAM goals for CDOT, as well as the current status relative to these goals. The Plan also provides a summary of the assets maintained by CDOT and an assessment of financial and risk considerations for these assets.

CDOT's current asset management strategy necessitates the integration of interdisciplinary knowledge and techniques into a new business model where a holistic approach is applied to asset management issues. TAM is the coordination and sequencing of CDOT's fundamental business processes. To implement TAM, the Plan documents:

- The current and forecasted condition of assets
- Asset performance goals established in policy
- A process for using analysis and data to inform decisions

- Specific investment strategies that CDOT will implement to maintain the transportation system at lowest life-cycle costs
- A framework for how risk will be included in TAM decisions

The Moving Ahead for Progress in the 21st Century Act (MAP-21), the federal transportation authorization passed in 2012, includes requirements for developing a risk-based asset management plan for structures and pavement on the National Highways System. The Plan that CDOT has developed goes beyond minimum requirements and focuses on a more comprehensive and systemic approach to TAM. CDOT staff has worked hard at incorporating TAM principles for the Department's various assets. These assets include structures, pavement, maintenance levels of service, roadway equipment, Intelligent Transportation Systems (ITS) equipment, buildings, tunnels, culverts, and rockfall mitigation sites.

TAM is about change. Tasks performed by a staff working committee significantly changed existing asset management models, and additional models are being developed. Improved project-selection processes have been recommended, and life-cycle treatments are being implemented to ensure that CDOT focuses on its most critical projects. TAM principles are moving from mere concepts to being institutionalized as better ways of doing business.

Much work remains. TAM is a continual improvement process, and CDOT is currently refining an implementation plan to address gaps identified in the Plan. The highest priority opportunities for further developing TAM capabilities include:

- **Developing and documenting the budget distribution, project selection and project tracking process**
- **Integrating risk analysis into planning and programming processes**
- **Developing strategies to manage project and program delivery risks**
- **Establishing a framework to evaluate alternative strategies for agency risks**
- **Analyzing budget tradeoffs across asset programs**
- **Improving project scoping and optimization**
- **Incorporating life-cycle analysis into decision-making**
- **Clarifying the role of performance target-setting**
- **Implement a strategic management framework to reflect on progress**
- **Communicating the benefits of TAM**

The mission of the Colorado Department of Transportation is *to provide the best multi-modal transportation system for Colorado that most effectively and safely moves people, goods and information*. Through the Risk-Based Asset Management Plan, and under the direction of the Transportation Commission, CDOT will implement TAM principles that ensure the most effective use of limited funds to maintain assets in support of CDOT's mission.

1.0 Introduction

Transportation asset management is defined 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]

In an era of constrained resources, effective management of transportation assets is becoming an increasingly important function of transportation agencies. Likewise, the latest Federal transportation reauthorization, Moving Ahead for Progress in the 21st Century Act (MAP-21), is further institutionalizing asset management by requiring that all state departments of transportation (DOTs) develop a risk-based asset management plan for the National Highway System (NHS).

Even before the MAP-21 legislation was signed into law, the Colorado Department of Transportation (CDOT) had embraced asset management as an important business practice for maintaining its assets in a state of good repair over the long-term with the least investment of resources. For example, since 2011 CDOT's asset managers have been working with the Multi-Asset Management System (MAMS, now renamed the Asset Investment Management System or AIMS) to develop budget scenarios and explore the relationship between funding and performance. CDOT is establishing risk-based asset management as the official approach for strategic preservation of the DOT's assets and related investment decisions for those assets.

1.1 Asset Management Goal and Objectives

The CDOT asset management process is also tightly linked to the department's mission and its framework for statewide transportation planning. This framework is defined by Policy Directive 14 (PD 14). PD 14 defines CDOT's transportation goals, objectives, and principles that guide the allocation of resources. As a result, PD 14 contains information vital to the implementation of asset management at CDOT.

CDOT's Mission

"To provide the best multimodal transportation system for Colorado that most effectively and safely moves people, goods, and information."

[1] American Association of State Highway and Transportation Officials' Subcommittee on Asset Management.

The overall goal of CDOT's asset management program is to minimize life-cycle costs for managing and maintaining the department's assets subject to acceptable levels of risk. The asset management program aligns with the department's overall mission, and uses the PD 14 goals and objectives to guide and inform asset management decisions. The current PD 14 language is provided in Appendix B, though the policy directive is in the process of being revised as part of CDOT's 2040 Statewide Transportation Plan effort. CDOT's goals, as defined in PD 14, are as follows:

1. **Safety –** Reduce traffic fatalities and serious injuries and work toward zero deaths for all users.
2. **Infrastructure Condition –** Preserve the transportation infrastructure condition to ensure safety and mobility at a least life-cycle cost.
3. **System Performance –** Improve system reliability and reduce congestion, primarily through operational improvements and secondarily through the addition of capacity. Support opportunities for mode choice.
4. **Maintenance –** Annually maintain CDOT's roadways and facilities to minimize the need for replacement or rehabilitation.

Of these four goals, No. 2 and No. 4 are directly related to asset management. PD 14 defines a set of objectives for each goal. CDOT defines objectives as specific target performance levels it intends to meet. Based on the policies established in PD 14 and this asset management plan, CDOT's asset management objectives are as follows. Some assets have additional objectives beyond those found in PD 14. See Table 4.1 for a list of all asset management objectives.

Asset Management Objectives – Bridges

- Maintain the percent of national highway system bridge total deck area that is not structurally deficient at or above 90 percent.
- Maintain the percent of state highway total bridge deck area that is not structurally deficient at or above 90 percent.
- Maintain the percent of bridges that are scour critical at less than 1 percent.
- Maintain the percent of bridges with vertical clearance over Colorado state highways less than the statutory maximum vehicle height (14 feet-6 inches) below 0.2 percent.
- Maintain the percent of bridges with vertical clearance over Colorado state highways less than the minimum design requirement (currently 16 feet-6 inches) below 2 percent.
- Maintain the percent of bridges posted for load at less than 0.1 percent.
- Maintain the percent of bridges with load restrictions at less than 2 percent.

- Maintain the percent of expansion joint length that is leaking at less than 10 percent.
- Maintain the percent of bridge deck area that is unsealed or otherwise unprotected at less than 5 percent.

Asset Management Objectives – Pavements

- Maintain 80 percent High/Moderate Drivability Life for Interstates based on condition standards and treatments set for traffic volume categories.
- Maintain 80 percent High/Moderate Drivability Life for the National Highway System (NHS), excluding Interstates, based on condition standards and treatments set for traffic volume categories.
- Maintain 80 percent High/Moderate Drivability Life for the State highway system based on condition standards and treatments set for traffic volume categories.

Asset Management Objectives – Maintenance

- Maintain an overall maintenance level of service (MLOS) of B- for the State highway system.
- Maintain an LOS B grade for snow and ice removal.

In addition to the above objectives, PD 14 formally establishes a policy of meeting the performance targets established in the RB AMP. The corresponding targets are presented in Section 4.0 of this document.

1.2 RB AMP OVERVIEW

CDOT's Executive Director and Transportation Commission have directed staff to follow an asset management approach. To communicate the importance of asset management to staff and to provide clarity on the processes currently in place, the Guidance for Asset Management was developed and will be provided to staff. This Guidance is provided in Appendix C.

Building from this guidance CDOT's Risk-Based Asset Management Plan (RB AMP) provides a comprehensive plan for implementing and sustaining TAM within the department. CDOT has developed this plan that:

- Documents the department's existing asset management practices;
- Presents a 10-year, fiscally constrained financial plan for managing CDOT's assets; and
- Establishes a blueprint for future improvements to the asset management program.

The benefits of creating and maintaining the RB AMP include:

- Communicating CDOT's asset management practices to its stakeholders;
- Tying together current planning and decision-making capabilities at CDOT;
- Defining a strategic management approach for asset management that enables continuous improvement, and creates a sustainable program;
- Addressing the department's strategic goals and objectives with a systematic process and specific actions needed to reach these goals;
- Evaluating and comparing the benefits of investment opportunities across programs and across performance-based investment candidates; and
- Articulating process and technology improvements that will enhance asset management over time.

Another key purpose of the RB AMP is to respond to the requirements of MAP-21. This RB AMP address the elements required by MAP-21, which include:

- Summary list, including condition, of the State's pavement and bridges on the National Highway System;
- Asset management objectives and measures;
- Performance gap identification;
- Life-cycle cost and risk management analysis;
- A financial plan; and
- Investment strategies.

The RB AMP also describes how risk is incorporated into CDOT's asset management process. CDOT's approach to risk management considers three levels – agency, programmatic, and project/asset level.

Finally, the RB AMP defines a comprehensive approach to program budgeting, project selection, and scoping that considers both risk and performance-based investments.

RB AMP Planning Horizon

This document provides a fiscally constrained plan for managing CDOT's assets over a 10-year planning horizon, from July 2014 to July 2024.

Assets Included in the RB AMP

The RB AMP addresses the following CDOT-owned assets:[2]

- Pavements;
- Bridges;
- Maintenance/traffic assets, such as signs and striping;
- Buildings;
- Intelligent Transportation System (ITS) equipment;
- Fleet (Road Equipment);
- Tunnels;
- Culverts; and
- Rockfall mitigation sites.

Plan Organization

The RB AMP is organized into two parts and a series of appendices. Part I presents a 10-year plan for managing CDOT's assets and Part II of the RB AMP presents a plan for improving asset management at CDOT. Part I consists of the following sections:

- **Section 2.0, Value to the Citizens –** This section presents a situation analysis of transportation in Colorado, including a summary of a recent survey of citizens. In this context, CDOT's Mission and Vision are examined, and the role of asset management in achieving them is described. This section also explores the role that the transportation system in terms of supporting Colorado's economy.
- **Section 3.0, Asset Inventory and Conditions –** Summarizes CDOT's assets. It answers two fundamental questions: What does CDOT own? What condition are they in?
- **Section 4.0, Performance Measures and Targets –** Defines a set of asset management performance measures and defines targets for each.
- **Section 5.0, Asset Management Process –** Describes CDOT's asset management process, including how funding decisions are made.

[2] The RB AMP addresses all pavements and bridges on the State system. The State system goes well beyond the National Highway System (NHS), which is the focus of MAP-21. However, the system does not include approximately 10 percent of the NHS.

- **Section 6.0, Life-Cycle Cost Considerations –** Discusses the importance of life-cycle costs and describes how they are considered in CDOT's asset management program.
- **Section 7.0, Risk Management –** Describes how CDOT is incorporating risk into its overall asset management program.
- **Section 8.0, Financial Plan –** Summarizes historical spending levels, and shows how future funds are planned to be distributed over a 10-year planning horizon.
- **Section 9.0, Investment Strategies –** Documents CDOT's strategies related to each asset class.

Part II consists of the following sections:

- **Section 10.0, Gap Assessment –** Provides a summary of a thorough asset management gap assessment that identified the highest priority items for TAM capability development.
- **Section 11.0, Implementation Plan for TAM Process Enhancements –** Presents a plan and schedule for implementing the process improvements identified in the gap assessment.
- **Section 12.0, RB AMP Governance –** Describes how CDOT will use, maintain, and update the RB AMP.

The appendices include:

- **Appendix A, MAP-21 Compliance –** This appendix cross-references the RB AMP contents with the list of MAP-21 requirements to illustrate how the RB AMP addresses them.
- **Appendix B, CDOT's Policy Directive 14 (PD 14).**
- **Appendix C, Guidance for Asset Management**.
- **Appendix D, Bridge Enterprise Project Prioritization Memorandum.**
- **Appendix E, List of Acronyms.**

Part I

Managing CDOT's Assets

2.0 Value to Citizens

This section describes the value of Colorado's transportation system to the citizens of Colorado. It summarizes findings from a recent survey regarding the public's perception of CDOT priorities, provides highlights from a recent study on the economic value of the transportation system and presents the projections of future demand for the system. These items provide context on why it is important to effectively manage Colorado's transportation system.

2.1 PUBLIC PERCEPTIONS OF CDOT'S ROLE AND RESPONSIBILITIES

CDOT conducted a phone survey in August 2011 to assess public priorities and gauge the opinions of Colorado citizens on various aspects of CDOT.[3] The survey solicited opinions on residents' overall approval rating of CDOT, a ranking of residents' priorities for the transportation system, the degree to which residents are aware of and satisfied with CDOT's roles and responsibilities, and perceptions of CDOT's credibility and efficiency. The survey also sought to capture differences in opinion between urban and rural areas of the State and the reasoning behind those differences.

With respect to overall priorities, nearly half of the Coloradans polled identified either government spending (25 percent) or economic issues (24 percent) as the most important problems for the State. Transportation issues came in third, identified by 16 percent of respondents as Colorado's most important problem. Education ranked in the top five priorities with 13 percent.

The survey also identified the citizens' suggested priorities for CDOT. Nearly two out of five respondents (39 percent) indicated maintaining existing highways and bridges should be CDOT's top priority. This is at the heart of the RB AMP. Maintaining the existing transportation network was followed by reducing congestion (14 percent) and increasing access (13 percent). Only 6 percent believe economic development is CDOT's top priority. The survey report indicated that "proactively promoting economic development is not something the general public feels CDOT has to do. People understand that CDOT is a major contributor to economic development, but they feel that it is more of a natural process than a forced one. If roads are being maintained and snow is being removed, people know that it has impacts on the economy."[4]

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[3] Summer 2011 CDOT Resident Survey, conducted by Corona Insights for CDOT, August 2011.

[4] Summer 2011 CDOT Resident Survey.

Overall, CDOT has a higher public approval rating than its state and Federal government counterparts. Approximately 79 percent of respondents trust CDOT to do what is best for the public, 78 percent approve of the job CDOT is doing, and 71 percent believe CDOT uses taxpayer dollars efficiently. (The efficient use of funds is one of the main objectives of CDOT's asset management program.) In comparison, approval ratings were 60 percent for state government overall and less than 25 percent for the Federal government.

At least 75 percent of respondents indicated that CDOT is acceptable or great at roadway signage and striping, snow and ice removal, communicating traffic information, designing roads and bridges, and managing road construction work. Potential areas of improvement for CDOT identified by at least 30 percent of respondents include pavement repair (including potholes), bicycle and pedestrian facilities on highways, traffic light synchronization, and bridge repair and replacement. Two of these items, pavement repair and bridge repair and replacement are addressed by the RB AMP.

Clearly, CDOT's efforts to develop a strategic, risk-based approach for managing the State's transportation assets aligns with public perceptions of CDOT's fundamental role. The RB AMP is intended to help the department continue to be a responsible steward of taxpayer dollars by improving how it makes decisions to optimize resources.

2.2 ECONOMIC IMPACT OF COLORADO'S TRANSPORTATION SYSTEM

During 2012 and 2013, CDOT commissioned a study to estimate the economic impact of the Colorado transportation system. The study quantified the value of the system by considering the following sources:

- **Consumer Value –** The study found that Colorado's households and businesses "indicate" the value of transportation in Colorado through the $54.8 billion they are willing to pay for the transport of people and goods each year.
- **Gross State Product –** The money that Coloradans spend on their transportation system each year enables Colorado's firms to create $10.7 billion worth of Gross State Product (GSP). This represents 4.4 percent of Colorado's GSP.
- **Jobs and Income –** Over 128,000 Coloradans are employed either producing or supplying services directly on Colorado's transportation system, or producing goods and services relying directly on transportation services as an input of production. These jobs accounted for over $6.8 billion in wage income to Colorado households, which represents 4.9 percent of all wage income earned in Colorado and 4.7 percent of all jobs in Colorado.

- **Exports –** Colorado firms sell $79 billion of goods and services to consumers in other states, bringing money directly into Colorado's economy in exchange for goods and services that rely on the transportation system to access markets elsewhere.[5]

Table 2.1 provides a breakdown of how each of these categories contributes to the Colorado economy as a whole. Overall, the study quantified the total value of the transportation system to the State's economy is $474 billion annually.

The results of this study help to illustrate the economic importance of an effective transportation asset management program. The current transportation system plays a significant role in supporting Colorado's economy by ensuring that the traveling public and business can move efficiently throughout the State. Therefore, preserving and improving this existing network is of vital importance.

[5] CDOT Transportation Investment Analysis Tool Kit, Task 2 Report, High Street Consulting, June 2013.

Table 2.1 Transportation's Contributions to the Colorado Economy

		Measures of Transportation Value (Annual)			
Source of Value	**Description**	**Dollars Paid by Users (in Millions)**	**Gross State Product Contribution (in Millions)**	**Wage Income (in Millions)**	**Employment (Jobs)**
Transportation services	Value of services provided by transportation service providers using the system directly	$17,833	$8,881	$5,707	105,012
Goods Produced from using transportation services	Transportation contribution (share) of the value of goods made and sold from nontransportation sectors	$4,014	$1,850	$1,154	22,926
Value accruing to households	Value of transportation used by households for nonreimbursed purposes	$32,940	N/A	N/A	N/A
Total value of transportation in Colorado		**$54,786**	**$10,731**	**$6,862**	**127,938**
Total Colorado economy		**$473,931**	**$281,921**	**$172,902**	**3,172,407**
Value of transportation as a percent of Colorado economy		4.6%	3.8%	4.0%	4.0%

Source: CDOT Transportation Investment Analysis Tool Kit, Task 2 Report.

2.3 TRAFFIC AND DEMAND ON THE SYSTEM

An important consideration in the asset management planning process is expected growth in demand on the system. As shown in Table 2.2, CDOT projects a 60 percent growth in traffic over the next 20 years. This level of projected traffic growth is an indication of increased economic activity. As traffic volumes increase, the importance of maintaining the existing network, wear and tear on the existing network, and pressure to provide money to capacity expansion projects also increase. Table 2.2 shows Colorado traffic in terms of daily vehicle miles traveled (DVMT).

Table 2.2 Current Traffic Data and Projections in for the State of Colorado in DVMT

	2012		2024		2034	
	Total	Truck	Total	Truck	Total	Truck
Interstate System	32,847,000	3,573,000	42,634,000	4,647,000	50,796,000	5,543,000
NHS	80,682,000	6,378,000	N/A	N/A	N/A	N/A
0n-State System, Non-NHS	8,889,000	833,000	12,663,000	1,212,000	15,810,000	1,527,000
On-State System, Total	76,945,000	6,740,000	100,275,000	8,910,000	119,739,000	10,721,000

Source: CDOT Staff.

Flat transportation revenues and increasing costs are making it difficult for transportation improvements to keep pace with the expected demand. With the recent escalation in roadway construction costs, CDOT's buying power has diminished at a time when demand for additional roadway capacity is increasing. Overall, planned expansion to the infrastructure cannot keep pace with projected travel demands. In 2008, the vehicle miles of travel (VMT) on state highways were projected to double between 2000 and 2034, yet the addition of new lane-miles was expected to be less than one percent. Given that CDOT does not have enough money to build all the new highways it needs to meet the growth in demand and subsequent increases in congestion, transportation asset management will play an important role in ensuring that the existing network does not go out of service.

2.4 SUMMARY OF CITIZEN VALUE OF ASSET MANAGEMENT

Taken collectively, the materials presented in this section illustrate three key points for CDOT's asset management program.

- **According to the recent survey, there is a high correlation of the need for asset management with the public's priorities.** Maintaining the State's highways and bridges is the public's number one priority for CDOT.
- **The existing transportation system has a significant impact on the economy of Colorado.** Therefore, managing the existing system, which is the focus of the RB AMP, is also of vital importance to the economy.
- **CDOT forecasts significant traffic growth over the next 20 years.** This growth increases the importance of the existing network, increases the wear and tear on these assets, and will likely increase pressure to provide funds to a capacity improvement program. Therefore, a proactive approach to managing and adapting to that growth will be critical. (This approach is outside of the scope of the RB AMP.)

For the reasons described above, asset management will be ever more important in maintaining the quality of Colorado's transportation infrastructure in a cost-effective manner. The considerations are varied due to the diverse nature of Colorado, from rural to urban, from mountainous terrain to agricultural land uses, and the myriad needs for a sound transportation system. In addition, asset management may enable CDOT to play a more proactive role in the future economy of Colorado.

The intended role of asset management at CDOT is to apply state-of-the-art processes and practices to the multifaceted realm of transportation investment in Colorado. With so many things to consider, it is essential that asset management capabilities be in place to meet the challenges ahead. Therefore, to avoid the risks associated with not being prepared for these challenges, it is important to implement the recommendations from the RB AMP.

3.0 Asset Inventory and Condition

This section summarizes the asset inventory and condition information for CDOT's major asset classes. It answers two questions that are fundamental to asset management: What does CDOT own? And, what condition is it in?

Table 3.1 Inventory and Condition Summary (On-State System)

Asset	Inventory Unit	2013 Inventory	Performance Measure	2013 Performance
Pavement	Lane-miles	23,024	Percent with high or moderate drivability life	82%
Bridge	Number of bridges	3,438	Percent deck area on bridges classified as structurally deficient	6.3%
Maintenance	N/A	N/A	Level of service	B-
Fleet	Number of vehicles	3,299	Percent of useful life	96%
ITS Equipment	Number of devices	2,024	Percent of useful life	143%
Buildings	Building	1,174	Letter grade	C or Better
Tunnels	Length in miles	6.9	Condition of manned tunnels	Good
Culverts	Number of culverts	6,668	Percent critical	4.4%
Rockfall	Sites/Corridors	760/38	Percent risk reduction of occurrence	TBD

3.1 PAVEMENT

Inventory

CDOT is responsible for a 9,106 centerline-mile highway system, accounting for 23,024 total lane-miles of pavement. Of this total, as shown in Table 3.2, approximately 18 percent of the State's lane-miles are on the Interstate System. Over half of the lane-miles for which CDOT is responsible are not included as part of the National Highway System (NHS). Centerline-miles represent the length of the road while lane-miles represent the length and lane count for a road.

Table 3.2 Pavement Inventory

	Centerline-Miles	Lane-Miles
Interstate System	952	4,141
On-State System, NHS[a]	3,471	9,337
On-State System, non NHS	4,683	9,546
On-State System, Total	9,106	23,024

[a] Figures represent the current NHS (post-May 2013 NHS). They do not include portions of the NHS that are off the State system. Approximately 10 percent of the NHS centerline-miles are not on the State system.

Condition

CDOT's main measure of pavement condition is "Drivability Life" (DL). DL 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 depth of rutting. Unacceptable pavement condition does not mean impassable; it means 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 CDOT drivability standards.

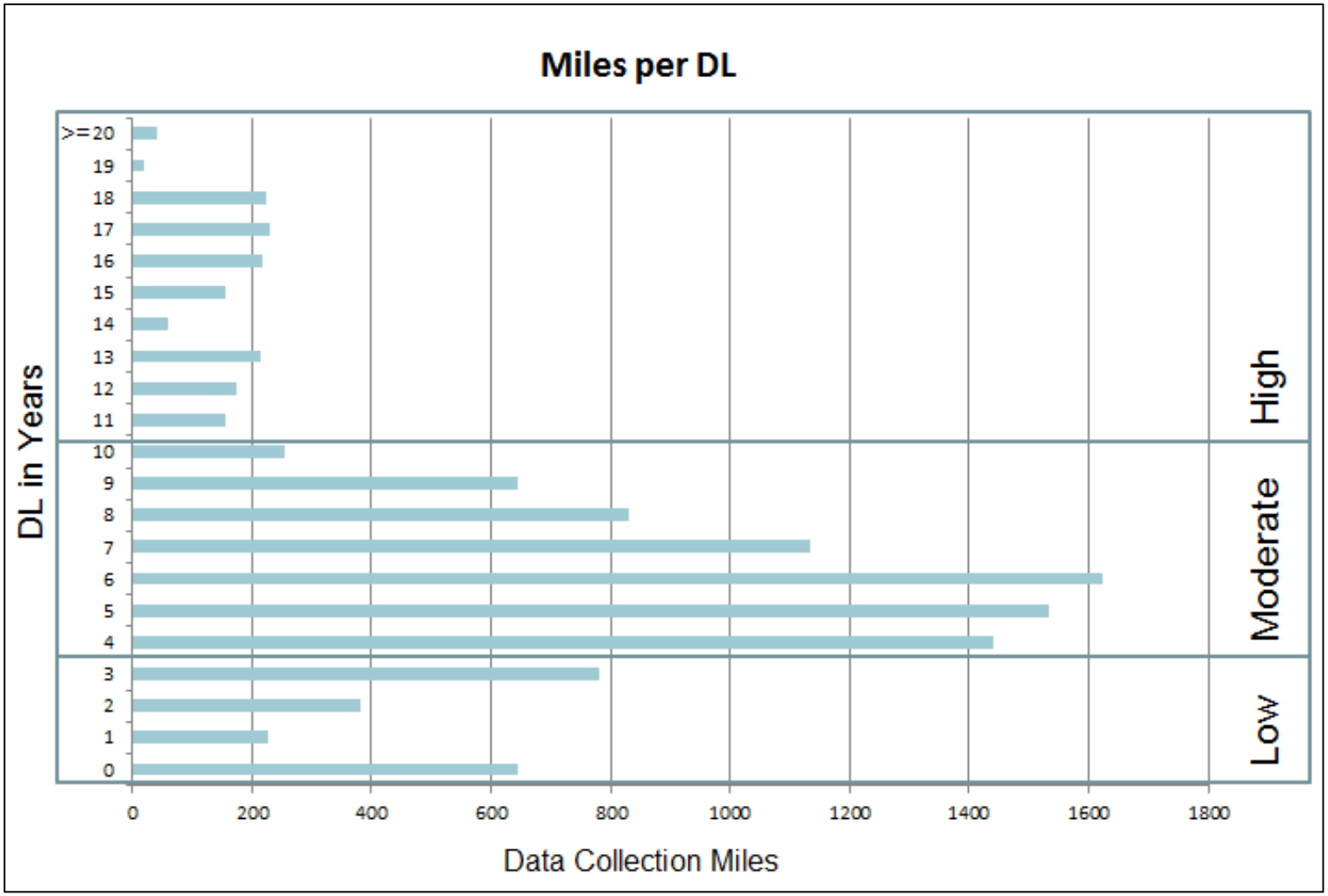
To determine DL for a segment of highway (0.5-5.0 miles in length), CDOT conducts a trend analysis using the following distresses:

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

The predicted future point at which any one of these distresses surpasses a predefined drivability threshold defines the DL of that segment. DLs are then grouped into three categories:

- High DL – Greater than 10 years;
- Moderate DL – From 4 to 10 years; and
- Low DL – 3 or fewer years.

Figure 3.1 Pavement Conditions



Source: CDOT.

Figure 3.1 shows the current condition distribution of pavement in Colorado, based on Drivability Life. The figure indicates that number of pavements close to falling into the Low category is significant and that this leads to the initial decline in condition given various funding levels seen in Figure 4.1 in the next section.

The four categories for treatment options are specific to the type of road as well (note AADTT refers to average annual daily truck traffic):

- Interstate;
- High-volume highways: AADT > 4,000 or AADTT > 1,000;
- Medium-volume highways: AADT 2,000-4,000 and/or Truck 100-1000; and
- Low-volume highways: AADT < 2000 and Truck < 100.

The acceptability thresholds vary by these traffic-based pavement categories and higher levels of distress are acceptable on lower volume roadways, as long as safe serviceable conditions exist. An index has been developed for each of the six surface distresses. Acceptability thresholds are currently being verified for the Interstates and are in progress for the lower categories.

Table 3.3 Pavement Condition Summary

	Percent Distribution		
	High DL	**Moderate DL**	**Low DL**
Interstate System	34	52	14
On-State System, NHS[a]	16	67	17
On-State System, non NHS	3	75	22
On-State System, Total	**14**	**68**	**18**

[a] Figures represent the current NHS (post-May 2013 NHS). They do not include portions of the NHS that are not on the State system.

Trends

In the past, based on CDOT's previous Remaining Service Life (RSL) model, CDOT RSL was predicted to drop approximately three percent Good/Fair every year at historical Surface Treatment funding levels ($150 million per year). Actual network deterioration in recent years was one percent to two percent Good/Fair per year, because of additional unanticipated Surface Treatment Revenues and effective regional planning. These historic RSL-based actual condition trends do not translate to the new DL model. CDOT has just recently finalized the predictive analysis portion of the new DL system. Actual drivability life data is available starting in 2013. Actual DL condition historic trends from year to year will be available starting in 2014. CDOT is establishing

stratified treatments and condition thresholds using traffic-based pavement categories.

3.2 BRIDGE

Inventory

CDOT owns and maintains approximately 3,400 bridges, as shown in Table 3.4. Bridges are defined within CDOT as Major Structures. Major Structures are those vehicular bridges 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. Most major structures are bridges. However, there are also large culverts (greater than 20 feet) within the population.

Table 3.4 Bridge Inventory

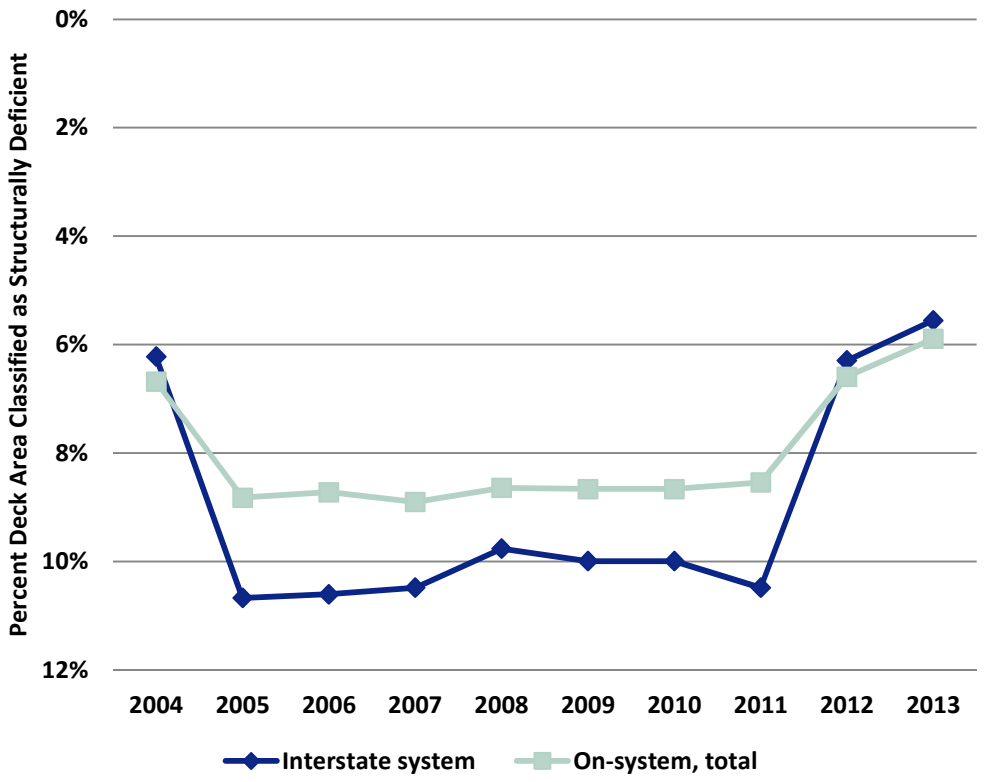
	Number of Bridges	Deck Area (square feet)
CDOT-owned NHS	2,298	25,252,948
Interstate System (all are CDOT-owned)	1,113	14,259,954
CDOT-owned, non-NHS	1,140	7,471,048
CDOT-owned, Total Bridges	**3,438**	**32,723,996**
Locally owned bridge on the NHS	436	5,143,333

Note: Based on April 2013 NBI tape data submitted to the FHWA (figures do not include the locally owned bridges on post-May 2013 NHS).

Condition

Figure 3.2 shows the condition of the State's bridges over the past several years in terms of the percent deck area classified as structurally deficient. Structurally deficient is a term used within the National Bridge Inventory (NBI) program to classify bridges that have a structural condition is less than fully adequate. A structural condition less than fully adequate refers to the NBI condition rating less than or equal to 4 on the deck, superstructure, substructure or culvert. An NBI condition rating of 4 or less will result in a structurally deficient classification. As illustrated in Figure 3.3, the condition rating scale goes from 0 to 9 where 0 means that that portion of the structure has failed and 9 means that that portion of the structure is in excellent condition.

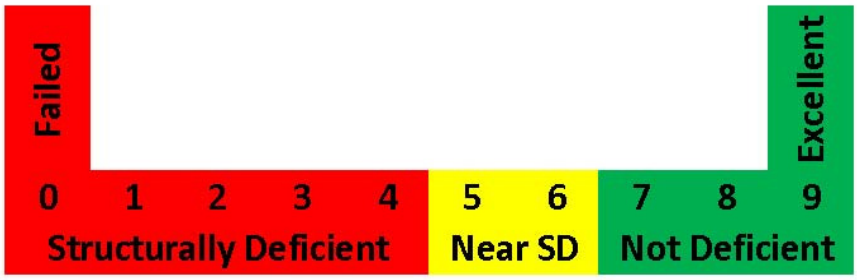
Figure 3.2 Bridge Condition Trend



Source: CDOT.

Note: Figures represent the current NHS (post-May 2013 NHS). They do not include portions of the NHS that are not on the State system.

Figure 3.3 NBI Rating Scale



Source: CDOT.

In Colorado, a structurally deficient bridge is typically one where corrosion or deterioration has resulted in a portion of the bridge being in poor condition; for example, where water leaking through an expansion joint has caused the end of a steel girder to rust. Depending on the degree of deterioration, bridges that are structurally deficient require additional monitoring, maintenance, or repair to ensure safety and continued service.

In the past, CDOT classified bridges on a good/fair/poor basis, and while these are no longer terms used for performance measures, CDOT still analyzes bridge data using these terms. Poor condition is defined as a Sufficiency Rating less than 50 and Structurally Deficient (SD) or Functionally Obsolete (FO). Fair condition is defined as a Sufficiency Rating from 50 to 80 and SD or FO. Good condition is defined as any bridge that is not Poor or Fair. In the past CDOT used these definitions for reporting performance measures, however new measures have been developed to align with MAP-21. These new objectives can be found in Table 4.1.

Trends

The State-owned bridge network currently meets the minimum threshold established by MAP-21 (at least 90 percent of deck area on bridges not classified as structurally deficient). While, overall, CDOT's bridges are in relatively good condition, many structures built in the 1950s are coming to the end of their designed service life. This means that they need major rehabilitation or even replacement at some point in the near to mid-term future. Currently, the backlog of SD bridges exceeds the available funding. In addition, the average age of bridge structures is going up. The next 10 years will see the largest population of Colorado's structures to ever meet the end of their designed service life, resulting in a considerable funding deficit in the next 10 to 20 years. CDOT anticipates that given available funding bridges will continue to meet their performance target over the next 10 years, however after 10 years there will be a decline in condition below the targeted level.

3.3 MAINTENANCE

Inventory

Throughout Colorado CDOT owns and maintains a large number of safety and traffic-related devices. In the past CDOT had completed annual inventories of these items, however due to budget constraints this annual inventory has not been completed in several years. The last inventory provided the counts listed below.

CDOT estimates that it maintains the following inventory:

- 192,000 signs;
- 493,000 delineators;
- 1,156,523 linear feet of cable guardrail;
- 7,363,119 linear feet of metal guardrail;
- 2,560,889 linear feet of concrete guardrail;
- 48,928 miles of striping;

- 52,862 square feet of pavement markings;
- 30,333 roadway lights;
- 2,000 traffic signals; and
- 1,958 attenuators.[6]

Condition

The nine Maintenance Program Areas (MPAs) include several that provide preservation activities in support of asset management. The Roadway Surface MPA (MPA 150) includes patching, pavement crack and joint sealing, seal coating, fog coating, blading, and base stabilization and repair activities. The Roadside Facilities MPA (MPA 200) includes the cleaning, repair, or replacement of minor drainage structures, slope repair, fence, gate, and cattle guard cleaning and maintenance, trash cleanup, and sweeping. The Traffic Services MPA (MPA 300) includes activities to maintain and replace signs, guardrail, striping, and traffic signals. The Structure Maintenance MPA (MPA 350) includes bridge/ structure cleaning, bridge deck repair, superstructure maintenance and repair, painting, bearing and substructure maintenance and repair, approach slabs and slope protection, and deck expansion maintenance and repair. The Rest Areas, Buildings and Grounds MPA (MPA 450) includes maintenance and repair for all buildings and grounds. The Tunnel Activities MPA (MPA 500) includes tunnel washing, maintenance of the tunnels electrical, mechanical and ventilation systems, and structural maintenance and repair.

The condition of maintenance assets is expressed as Maintenance Levels of Service (MLOS) grades. CDOT determines MLOS grades based on six field surveys conducted each year that convey how well CDOT's infrastructure has been maintained. Each survey corresponds to an MPA(s) and each survey question corresponds to a maintenance activity/activities, as follows:

- Spring Survey – MPA 300 (Traffic Services);
- Summer Survey – MPAs 150, 200, 250, 300 (Roadway Surface, Roadside Facilities, Roadside Appearance, Traffic Services);
- Winter Survey – MPA 400 (Snow and Ice Control);
- Building Condition Survey – MPA 450 (Rest Areas, Buildings, Grounds);
- Bridge Condition Survey – MPA 350 (Structure Maintenance); and
- Tunnel Condition Survey – MPA 500 (Tunnel Maintenance).

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[6] These values reflect values from 2006, the year in which CDOT performed its most recent complete inventory.

Each survey question carries different weight in the overall survey score. The spring and summer surveys both include traffic assets. Table 3.5 illustrates how LOS survey scores equate to grades.

Table 3.5 MLOS Letter Grades

Letter Grade	MLOS Score Equivalent
A+	1
A	2
A-	3
B+	4
B	5
B-	6
C+	7
C	8
C-	9
D+	10
D	11
D-	12
F+	13
F	14
F-	15

Trends

CDOT's statewide level of service has remained relatively the same for the past five years. When comparing FY 2009 to FY 2013, CDOT improved the levels of service in the 300 (Traffic); 400 (Snow and Ice); and 450 (Equipment, Buildings and Grounds) Maintenance Program Areas. Table 3.6 highlights traffic-related assets rated in the past by annual surveys as part of the MLOS program. An inventory on these items has not occurred in several years due to a lack of funding. This inventory could be resurrected if asset management analysis supports the need for this type of data.

Table 3.6 Select Statewide MLOS Grades

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Overall MLOS	B	B	C-	C+	C+	C+	B-	B-	C+	B-
Nonsigning and striping assets	A	B+	B-	B+			N/A			
Striping assets	C	C+	D-	D+			N/A			
Signing assets	A-	B+	C+	B+			N/A			

Note: Some data are not available because the last inventory was performed in 2006.

3.4 BUILDINGS

Inventory

CDOT has several types of buildings within its inventory, as listed in Table 3.7. Most of the buildings require maintenance. CDOT owns and maintains vehicle storage facilities, maintenance buildings, sand sheds, office and lab facilities in addition to a limited number of employee housing buildings, including houses, duplexes, mobile homes, and mobile home pad sites. Mobile homes that are owned by employees that are parked on CDOT pad sites are not included in CDOT's building inventory. Note that the items in the "New Planned for 2013-2017" column refer to replacing existing buildings for Maintenance/repair and Office facilities, while the count for Sand Shed and Traffic facilities refer to brand new buildings.

Table 3.7 Building Inventory

Building Type	Current Count	New Planned for 2013-2017
Employee housing	94	0
Lab	10	0
Maintenance/repair	297	9
Office	74	2
Rest area	192	0
Sand Shed	146	34
Storage Shed	344	0
Traffic shop	13	1
Unknown	4	0
Total	**1,174**	**46**

Condition

CDOT evaluates each building based on a multitude of functional, structural, and mechanical criteria. Each of the criteria are weighted, totaled, and averaged

to determine an overall building grade (letter grade A-F). Each building is rated on a yearly interval. The current condition (August 2013) of CDOT's building assets are summarized in Table 3.8.

Table 3.8 Building Conditions

	Count in Each Condition Category				
Building Type	**A**	**B**	**C**	**D**	**F**
Employee Housing	20	31	35	8	0
Lab	4	4	1	0	1
Maintenance/Repair	38	92	76	29	62
Office	13	48	10	1	2
Rest Area	77	81	24	9	1
Sand Shed	59	63	17	5	2
Storage Shed	114	118	67	22	23
Traffic Shop	5	6	0	2	0
Unknown	0	2	2	0	0

CDOT has recently developed a revised set of rating criteria that incorporates more systems criteria for maintenance buildings, along with separate criteria for office buildings. Under the previous evaluation method, a single set of criteria were used to assess all building types, with the focus on the physical condition of structures and systems. The new evaluation method streamlines the physical condition assessment and adds employee satisfaction and the efficiency of the building criteria. The new evaluation method was implemented in the field during October and November of 2013 with an expectation that the results will be ready for analysis in early 2014.

Trends

Region boundary changes during the spring of 2013 and continuing efficiency analysis conducted by Region maintenance superintendents resulted in more consolidations of maintenance patrols in 2013 than have been seen in the past. These consolidations require the construction of new vehicle storage faculties that are often 14- to 18-bay facilities and can cost approximately $3.5 million each. Another trend affecting Property Management is that maintenance equipment such as trucks and snowplows continue to increase in size. When vehicle storage facilities can no longer house the road equipment, they fail to meet their use and receive lower grades, becoming "D"- or "F"-rated buildings. No amount of preventative maintenance can stop this trend from occurring.

3.5 ITS EQUIPMENT

Inventory

CDOT deploys and tracks various ITS devices such as Closed Circuit televisions (CCTV), Vehicle Message Signs (VMS), Travel Time Indicators (TTI), and others to gather data and information to disseminate to motorists. This information is used to assist in decision-making and maintain the flow of traffic on Colorado's highways. Table 3.9 summarizes CDOT's ITS inventory. Note that the devices in the "New Planned for 2013-2016" column are all new devices in new locations, with the exception of the "Network Equipment" which is a combination of replacing equipment and new equipment to operate the increased inventory.

Table 3.9 ITS Inventory

Category	Count (December 2012)	New Planned for 2013-2016
ITS Devices		
Closed Circuit Video Camera (CCTV)	320	335
Microwave Vehicle Radar Detector (MVRD)	174	146
Road and Weather information Station (RWIS)	91	73
Travel Time Indicator (TTI)	177	167
Blank Out Signs	45	10
Variable Message Sign (VMS)	386	60
Equipment Node Buildings	30	6
Emergency Call Boxes	97	5
Automated Traffic Recorders (ATR)	116	20
Weigh-In-Motion Sensors (WIM)	14	2
Ramp Meters	76	15
Highway Advisory Radios (HAR)	14	0
Network Equipment	264	Updates
Other	220	50
Fiberoptic Cable (miles)	864	448
Total (excluding fiber optic cable)	**2,024**	**889 + updates**

Note: On July 1, 2013 the ITS inventory increased by 450 traffic signals due to an overall organizational restructuring. Although these devices are not yet able to be included in calculating the performance gap for this document, it is important to note the rapid expansion of the ITS program.

Condition

CDOT uses "useful life" to communicate the condition of ITS equipment. Useful life, which is specific to each device type, is defined as the length of time that a device is expected to provide CDOT with adequate data and information needed to keep up with CDOT's goals for the traveling public. The current average percent of useful life expended is shown in Table 3.10. A value of 100 percent indicates that a piece of equipment has reached its useful life. Values greater than 100 percent indicate that equipment has exceeded its useful life.

Table 3.10 Condition of CDOT's ITS Assets

Category	Average Percent Useful Life
Closed Circuit Video Camera (CCTV)	157%
Microwave Vehicle Radar Detector (MVRD)	37%
Road and Weather information Station (RWIS)	146%
Travel Time Indicator (TTI)	46%
Variable Message Sign (VMS)	69%
Emergency Call Boxes	222%
Automated Traffic Recorders (ATR)	184%
Ramp Meters	115%
Weigh-In-Motion Sensors (WIM)	169%
Network Equipment	105%
Average Percent Useful Life for all ITS Devices	**143%**

Useful life for an ITS device is based on:

- Primarily the manufacturer's specification, along with consideration for the ITS office's maintenance personnel experiences and recommendations;
- Changing technologies such as software advances that may affect maintenance costs or the ability to assimilate the data to remain useful;
- Obsolescence considerations;
- General maintenance costs; and
- Geographic locations of the device (i.e., is the device at 8,000 feet in mountainous regions where snow is likely or at 4,500 feet on the plains where high winds and snow occur).

CDOT also considers FHWA's lists of device life cycles. FHWA conducts state surveys and compiles the results to develop their own device life-cycle lists.

Trends

Over the past several years, as part of the ITS Capital Replacement Program and other projects, CDOT has funded and replaced a significant number of ITS devices, including variable message signs, CCTVs, radar units in the Denver Metro area, weather station controllers, weigh-in-motion scales, and other assets which has improved the overall condition of the statewide ITS infrastructure. In addition, CDOT is committed to ensuring that each device is tracked within the ITS Management database (SAP) and work orders are used in the performance of all maintenance activities in order to monitor and report device condition and maintenance costs. These steps, in conjunction with additional funding resources (RAMP and other) to meet ITS infrastructure needs, seem to indicate that ITS assets are an important feature of CDOT's highway system. They show a favorable and positive trend to maintaining and growing a viable statewide ITS infrastructure.

3.6 FLEET

Inventory

CDOT manages a fleet of almost 3,300 vehicles used for road construction, maintenance, and general purpose activities. Table 3.11 summarizes CDOT's fleet inventory. Note that the items in the "New" column refer to new equipment ordered to replace older equipment.

CDOT is moving to a standardized process to improve the speed of ordering specialized equipment and the training for employees for all vehicle types. CDOT has gone from 86 Tandem vehicle options to 12, so that the equipment across the regions is the same, and training is consistent for staff throughout Colorado. Every truck is being standardized starting with the bids starting in FY 2014. The vendors are able to use one template for "allieds" (the chassis, the wings, the plows, the wiring, hydraulics) and therefore fill the order quicker and eliminating change orders.

Colorado's terrain is one of the reasons people move to the State. However, it also provides unique challenges for keeping the traveling public safe. Maintaining clear mountain passes at 10,000 to 13,000 feet with medium and heavy fleet equipment results in special vehicle configuration and driver training. Ninety percent of CDOT's road equipment vehicles have automatic transmissions, while 10 percent have standard transmissions. Generally, dump trucks used on the mountain passes need 18 gears to give them better range of power. The drivers stay lower on the torque curves on the passes.

Table 3.11 Fleet Inventory

Vehicle Group	Current Count	New Planned for 2013-2017
Trucks	1,610	295
Trailers	261	30
Loaders	251	36
Rollers	55	6
Snow Blowers	43	14
Sweepers	106	33
Paint	29	5
Motor Graders	102	24
Safety	284	10
Drill	23	3
Fork Lifts	35	5
Asphalt	124	17
Weed and Grass	244	44
Excavator	42	5
Drain	14	0
Miscellaneous	76	10
Total	**3,299**	**537**

Condition

CDOT currently assesses the condition of its road equipment in terms of age and usage. Direction on how to conduct the fleet analysis is provided in CDOT's Policy Directive 9.2 (PD 9.2). PD 9.2 is currently being revised to reflect a new methodology being discussed by the Equipment Management Advisory Committee (EMAC), which will incorporate a net present value analysis of replacing versus maintaining equipment, in addition to age and usage for the FY 2016 Fleet Equipment Replacement plan.

The current condition of CDOT's road equipment fleet is shown in Table 3.12. On average, the vehicles in the fleet are 12.9 years old.

Table 3.12 Average Age and Condition of CDOT's Fleet

Vehicle Group	Average Age	Percent Useful Life
Trucks	12.3	97%
Trailers	14.3	90%
Loaders	15.0	98%
Rollers	15.6	88%
Snow Blowers	17.0	117%
Sweepers	13.3	117%
Paint	16.7	116%
Motor Graders	10.8	83%
Safety	9.9	89%
Drill	16.7	85%
Fork Lifts	15.4	80%
Asphalt Equipment	13.8	98%
Weed and Grass	14.5	102%
Excavators	15.2	96%
Drain Cleaning	12.1	87%
Miscellaneous	16.7	86%
Average	**12.9**	**96%**

Trends

CDOT has a large group of vehicles at the end of their useful life, followed by a gap before the next wave of vehicles needing replacement. Instead of waves of vehicles to be replaced as in the past, the desired state is a steady flow of new vehicles replacing older vehicles each year. This requires additional funds to start with to overcome the backlog of replacements needed, and then a steady stream of funding for needed replacements. The tandems and the single-axle snowplows are used year-round (plows minus blades in summer) and tend to exceed useful life faster than other vehicle types. The replacement for these vehicles is approximately $200,000 each.

3.7 TUNNELS

Inventory

CDOT is responsible for managing a total of 21 tunnel bores throughout the State with a total length of 6.9 miles (Table 3.13). Four of these tunnel bores are manned, meaning they have a consistent staff on-site to operate and maintain the facility.

Table 3.13 Current Tunnel Inventory

	Number of Tunnel Bores	Length (Miles)
Manned	4	4.9
Unmanned	17	2.0
Total	**21**	**6.9**

Condition

The overall condition of Colorado's manned tunnel bores, including the two at Eisenhower-Johnson Memorial Tunnel (EJMT) and the two at Hanging Lake Tunnel (HLT), is good. There are 17 unmanned tunnel bores and snow sheds, which are inspected bi-annually for an assessment of any changed conditions by bridge inspection teams. CDOT expects Federal rules on tunnel inspection requirements to promulgate soon. CDOT is in the process of hiring a consultant to prepare guidance on tunnel inspection procedures and to update the tunnel inventory. In preparation for the new Federal rules, CDOT has had consultants in to perform structural baseline inspections and follow up inspections at both Eisenhower Johnson Memorial Tunnel and at Hanging Lake Tunnel.

Trends

Collecting the data required for assessing the condition of CDOT's tunnels is a work in progress. A complete assessment of tunnel condition is needed to provide an accurate representation of tunnel condition. Inspecting the tunnels requires a multidisciplinary team to inspect the geotechnical structure, structural elements, tunnel systems, and life safety components. Although these data are not currently available, CDOT's tunnel operations experts believe that the overall condition of the superstructure in the tunnels is slowly declining due to age. The electrical systems, mechanical systems, and other tunnel elements that are required to safely operate the tunnels for the motoring public are declining at an accelerated pace with replacements currently needed in several locations across the State.

3.8 CULVERTS

Inventory

CDOT defines culverts as minor structures that have a clear opening of less than or equal to 20 feet along the direction of the roadway. Most minor structures are culverts, but there are also some minor bridges within the inventory. There are 6,668 minor structures on state highway system.

CDOT also tracks a category called major structures. Major structures include those culverts with a clear opening of greater 20 feet along the direction of the

roadway. Most major structures are bridges, but there are culverts within the inventory (refer the bridge section for an inventory of major structures).

Condition

CDOT inspects both major and minor structures using the National Bridge Inspection Standards (NBIS) and the AASHTO Commonly Recognized Element (CORE) inspection. To date the Minor Culverts are not currently segregated into condition states of Good, Fair and Poor. Instead, the primary deliverable has been the identification of minor structures with Essential Repair Findings (ERF).

Table 3.14 Culvert Condition

Minor Structures	Count	Percent of On-State System Total
Minor Structures with ERFs (Critical Culverts)	292	4.4%

In the future, minor structures will be segregated by condition into Structurally Deficient (SD) (National Bridge Inventory (NBI) condition rating < 5) and Not SD and perhaps a segment of Not SD that is Near SD (NBI condition rating = 5). In addition, this may evolve into a condition (health) index based on more than the NBI condition rating alone.

Trends

The minor structure inspection program is relatively new when compared to the major structure inspection program. As such, the identified population of minor structures (culverts) that have essential repair findings is high compared to major structures (bridges).

Within both the minor and major structures it appears that the life span of steel culverts is relatively short because of the higher percentage of steel culverts that have an Essential Repair Finding compared to other types of culverts. The primary deterioration observed in steel culverts is the corrosion of the invert until it is perforated. Once the invert is perforated, the water starts to pipe through the fill under the culvert. Once the perforation leads to significant loss of structural capacity, the culvert starts to fail. Failure is evidenced by an upward projection of the invert into the culvert opening. Abrasion of the zinc galvanizing from the steel by transported material, chemical properties of the backfill, and chemical properties of the water are all primary suspects that shorten the life of these structures below a desired 75-year designed service life. In addition, it could be that steel culverts simply do not have the service life of precast or cast-in-place concrete culverts in Colorado.

3.9 ROCKFALL MITIGATION SITES

Inventory

CDOT currently manages 760 rockfall mitigation sites throughout the State. Most are located on the 38 identified high-risk corridors, although some are considered outliers and are located elsewhere.

Condition

CDOT is developing a new risk-based method for evaluating rockfall mitigation sites. A rockfall site on a corridor is evaluated by measuring the risk posed by the site to the corridor. The measurement term used is Rockfall Vehicle Exposure Score (VE). VE is based on three components:

- **Average Annual Daily Traffic (AADT),** which is used as a proxy for the consequence of a rockfall event.
- **Likelihood of a Vehicle Being Affected by a Rockfall Event**, which uses a combination of site distance, number of rockfall-caused accidents, and average vehicle risk, a measurement of the percentage of time throughout the day a vehicle is below the hazard.
- **Reduction Factor**, which reduces the VE score by an empirical effectiveness rating of existing mitigation.

Table 3.15 lists the VE scores of 38 corridors throughout Colorado. This table does not include the list of outlier sites, which are those sites that do not fall on identified corridors. There are approximately 50 rockfall hazard sites statewide considered to have a high rockfall risk that do not fall within a tier one rockfall corridor. These sites are assessed for mitigation needs individually according to overall corridor risk, region input and available funding.

Table 3.15 Rockfall Corridor Vehicle Exposure Scores
Does Not Include Outlier Sites

Corridor	Number of Sites	Average VE	Total VE
Clear Creek	53	97.3	5,159
U.S. 36 Lyons	6	94.5	567
I-70 Floyd to Dowd	36	85.3	3,072
U.S. 24 W Co Springs	11	82.9	906
U-70 Debeque	17	65.5	1,113
U.S. 34 Big Thompson	27	65.4	1,765
SH 74 Morrison	11	65.1	717
I-25 Raton Pass	11	65.0	715
SH 9 Kremmling	7	59.5	416
SH 149 Lake City	16	55.6	890
I-70 Rifle	5	55.3	221

Corridor	Number of Sites	Average VE	Total VE
U.S. 285	19	54.5	1,036
SH 119 West of Boulder	33	47.1	1,555
SH 14 Poudre Canyon	27	42.1	1,136
SH 145 Rico	8	41.1	329
U.S. 40 Berthoud Pass	33	40.9	1,349
SH 103 Mt Evans	9	38.0	342
U.S. 50 West of Canyon City	29	37.4	1,084
U.S. 50 East of Salida	21	36.6	768
U.S. 50 Blue Mesa	15	33.4	501
U.S. 285 Monarch Pass	27	32.7	883
SH 65 Grand Mesa	15	32.5	488
U.S. 550 Red Mountain	28	31.8	890
SH 82 Glenwood to Aspen	11	31.4	347
SH 12 Weston	7	30.7	215
SH 165 Rye	30	30.5	914
US40 Steamboat-Rabbit Ears	12	28.6	343
SH 82 Indy Pass	17	28.3	480
U.S. 40 Kremmling	12	28.3	340
SH 133 McClure Pass	31	28.1	874
Peak to Peak	41	23.9	978
SH 17 Antonito	8	22.5	180
U.S. 160 Wolf Creek Pass	10	22.3	223
SH 139 Douglass Pass	12	21.0	252
Durango Hub	13	20.8	271
SH 141 Naturita	16	20.1	323
SH 13 Craig to Meeker	5	19.9	100
U.S. 40 Mt Vernon	6	19.6	118
Total Sites	**694**		

Trends

CDOT's Rockfall Management Plan – Working Draft Under Development – has changed the site selection method from a top down approach that focuses on single sites to one that focuses on measurable risk reduction statewide. The Rockfall Management Plan, and eventually a more encompassing geological hazard and geotechnical asset plan, rates corridors with rockfall hazards according to an average corridor VE (Table 3.15). Reducing rockfall risk for a corridor instead of a single site is more meaningful and efficient than a top down approach that focuses on single sites. However, it is understood that not all sites with significant VE fit into a corridor approach. These "High-Risk Outlier" sites will be considered individually and incorporated into the Rockfall Management Plan as required.

4.0 Asset Management Performance Measures and Targets

This section presents a set of performance measures and targets used as part of CDOT's asset management program.

4.1 ASPIRATIONAL AND FISCALLY CONSTRAINED TARGETS

Some targets are long-held goals of the department and are referred to as "aspirational." These targets are set as part of the statewide planning process. They reflect a desirable level of service, should CDOT receive revenues beyond those projected. The current fiscal environment, however, consists of limited revenues, and reduced buying power. Therefore there is a need for fiscally constrained targets.

In addition to aspirational targets, CDOT has developed a set of fiscally constrained targets. These targets are achievable with available funding over the 10-year planning horizon of the RB AMP. In Section 5.0, "Asset Management Processes," the process for distributing funding is laid out. As part of this process, funding levels and target performance levels are linked and decision-makers establish these values simultaneously. As shown in the following sections, CDOT has developed or is in the process of developing a 20-year performance versus funding curve for each asset class. Using these curves, it is possible to determine the performance level that can be achieved with a given budget, and a budget that is required to achieve a specified performance level.

As discussed above, CDOT's Policy Directive 14 (PD 14) establishes a set of pavement, bridge and maintenance objectives that are expressed in the form of performance targets. Members of the Statewide Planning Committee of the Colorado Transportation Commission discussed these targets in the summer and fall of 2013. After reviewing the forecasted revenues for the 2040 Statewide Plan, the targets were selected and incorporated into PD 14. The targets in PD 14 are meant to be achievable over time with baseline revenue dollars and are therefore considered fiscally constrained.

In addition to the bridge objectives and targets established in PD 14, CDOT has established additional bridge objectives and targets based on staff's expertise. The additional targets are also considered fiscally constrained.

With fiscally constrained targets being determined as described above, each asset class target may increase or decrease relative to the coming 10-year period, depending upon the outcome of the planning budget exercise. As examples, PD 14 has stated a performance target for bridges of 10 percent or less structurally deficient (SD) bridges, weighted by deck area. Maintenance has a performance target for achieving a B- MLOS for the Snow and Ice Maintenance Program Area. These targets are used by decision-makers as guidance when they set the budgets for these assets.

Given that CDOT has established two sets of targets, a "performance gap" then results when there is a difference between the aspirational and fiscally constrained targets. The two types of targets for each of the asset classes and the corresponding performance gap are shown in Table 4.1.

4.2 PERFORMANCE VERSUS FUNDING SCENARIOS

In support of the program budget process described in Section 5.0, CDOT has developed a series of performance curves that illustrate the relationship between funding and future performance level. These curves, presented in the figures below, represent a range of options for the performance of the transportation network. The fiscally constrained targets presented in Table 4.1 reflect a combination of these curves and the budget levels presented in the Financial Plan in Section 9.0.

Table 4.1 CDOT Objectives and Targets (From PD 14 and Additional Developed by Staff)

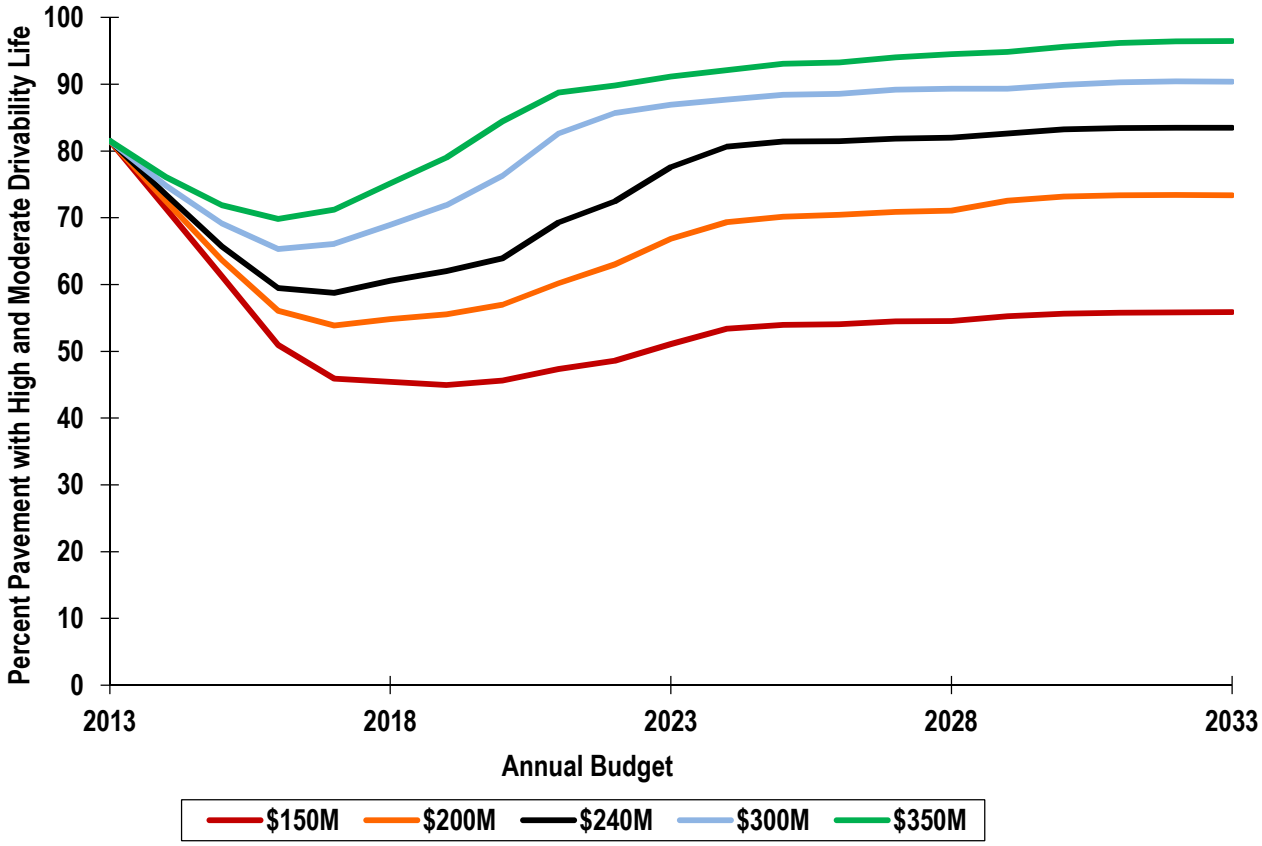
Asset	Measure	Current Performance	Aspirational Target	Fiscally Constrained Target	Performance Gap[b]
Bridges	Percentage of deck area on structurally deficient CDOT-owned bridges	6%	5%	10%[a]	5%
	Percentage of deck area on structurally deficient bridges on the NHS	5%	5%	10%[a]	5%
	Percentage of CDOT-owned bridges over waterways that are scour critical	6%	1%	5%	4%
	Percentage of bridge crossings over Interstates, U.S. routes and Colorado state highways with a vertical clearance less than the statutory maximum vehicle height of 14 feet-6 inches	1%	0%	1%	1%
	Percentage of bridge crossings over Interstates, U.S. Routes and Colorado state highways with a vertical clearance less than the minimum design requirement of 16 feet-6 inches	8%	2%	7%	5%
	Percentage of CDOT-owned bridges posted for load	0%	0%	0%	0%
	Percentage of CDOT-owned bridges with a load restriction	3%	1%	3%	2%
	Percentage of leaking expansion joint by length on CDOT-owned bridges	18%	5%	15%	10%
	Percentage of CDOT-owned bridge deck area that is unsealed or otherwise unprotected	41%	5%	30%	25%
Pavement	Percentage high-moderate drivability life for Interstates based on condition standards and treatments set for traffic volume categories	86%	90%	80%[a]	10%
	Percentage high-moderate drivability life for CDOT-owned NHS, excluding Interstates based on condition standards and treatments set for traffic volume categories	83%	90%	80%[a]	10%
	Percentage high-moderate drivability life for the State highway system based on condition standards and treatments set for traffic volume categories	82%	90%	80%[a]	10%
Maintenance	Statewide Letter Grade	B-	B-	B-[a]	None
Buildings	Statewide Letter Grade	86% C or Better	100% C or Better	90% C or Better	10%
ITS	Average Percent Useful Life	143%	80%	104%	24%
Fleet	Average Percent Useful Life	96%	70%	TBD	TBD
Culverts	Percentage Critical Culverts	4.4%	2%	5%	3%
Rockfall	Vehicle Exposure Score	TBD	TBD	TBD	TBD
Tunnels	TBD	TBD	TBD	TBD	TBD

[a] These objectives and targets are from PD 14, adopted by the Transportation Commission. Others are staff recommended, and subject to available funding.

[b] CDOT defines the performance gap as the difference between aspirational and fiscally constrained targets.

The pavement performance curve presented in Figure 4.1 is based on FY 2013 data, and refers to the new Drivability Life measure. The curves show a substantial decrease in performance in the early years of the analysis because over half of the network falls into the Moderate category, and without additional funding those segments would fall into the Low category.

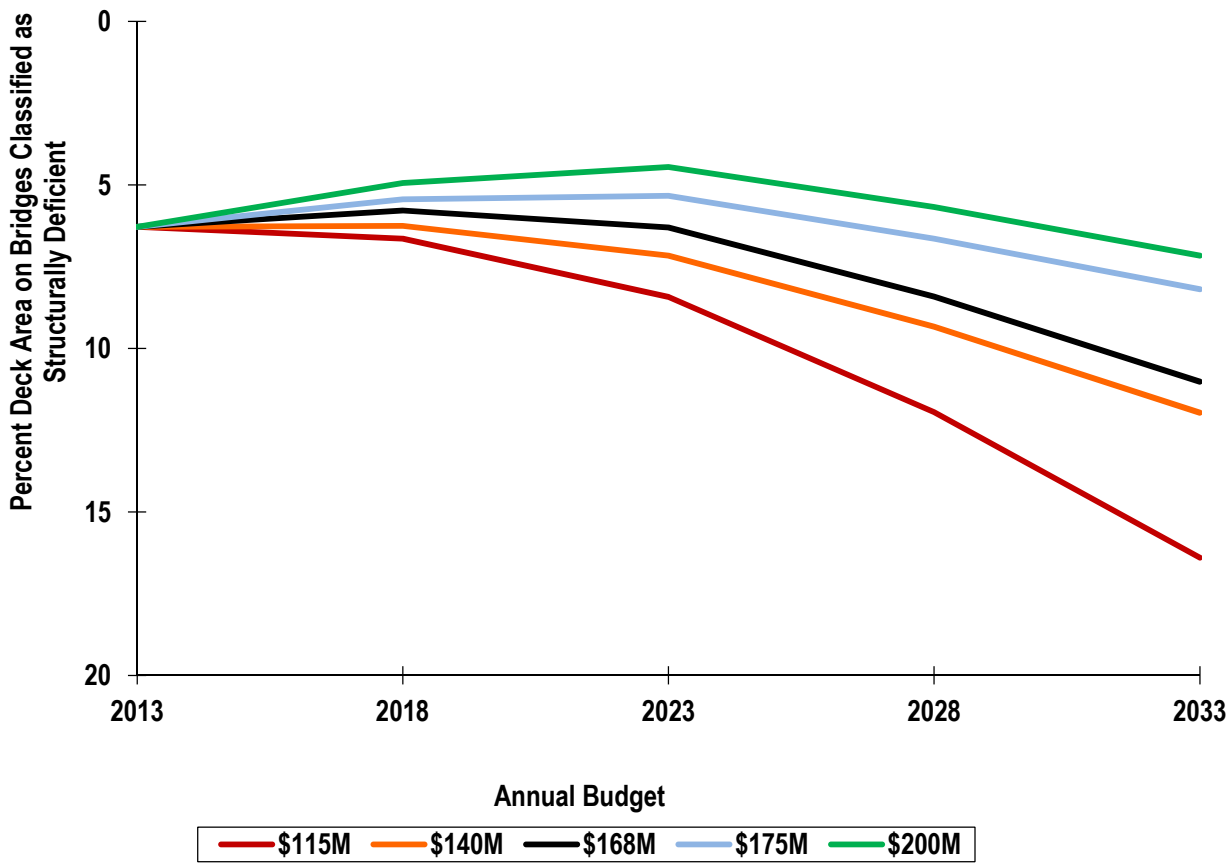
Figure 4.1 Pavement Performance versus Funding



Source: CDOT

The bridge performance curve presented in Figure 4.2 is also based on FY 2012 data. It reflects CDOT's new bridge measure, which is based on percent deck area on bridges classified as structurally deficient. The $168 million curve shown in black represents CDOT's FY 2015 budget for bridge (including bridge enterprise and RAMP funding).

Figure 4.2 Bridge Performance versus Funding



Source: CDOT.

4.3 LEVELS OF SERVICE

Most of the performance targets defined in Table 4.1 reflect a condition-based level of service that the transportation network should provide. Two of them reflect the customer level of service that CDOT would like to provide to the traveling public. These include "Drivability Life" for the Pavement performance measure, and MLOS letter grade scores for Maintenance (Maintenance Levels of Service). Instead of portraying the engineering or science-based measures of performance, such as specific indicators for roughness, rutting, and distresses, the Drivability Life measure includes some engineering measures but also

attempts to capture how the public is judging the road quality. Likewise, for MLOS, the grade scores are communicating a measure that resonates with the public in terms of their experiences in driving the roads of Colorado. Refer to Section 3.0 for details on both of these measures.

The Drivability Life analysis for pavement includes criteria that vary by category. These categories are noted here:

- **Interstate** shall be constructed, rehabilitated, and maintained in accordance with AASHTO Pavement Design Standards, ensuring that Interstates meet Federal standards and provide reliable service to the traveling public.
- **High-Volume (NHS and Other)** shall also follow AASHTO Pavement Design Standards. These highways serve a large segment of the traveling public and provide critical routes for significant transportation of goods and services across regional boundaries. High-volume roads are those with an AADT greater than 4,000 or AADTT greater than 1,000.
- **Medium Volume (NHS and Other)** highways shall be treated primarily with minor rehabilitation and pavement maintenance treatments. Major rehabilitation can be considered when drivability is unacceptable and project-level analysis reveals a compromised pavement structure. Medium Volume roads are those with an AADT between 2,000-4,000 and/or AADTT between 100 and 1000.
- **Low-Volume (NHS and Other)** highways are to be maintained at acceptable drivability standards with pavement maintenance treatments. If formally approved by the Chief Engineer, minor rehabilitation treatments may be used only as needed to return the pavement to acceptable drivability condition. Low-volume roads are those with an AADT less than 2,000 and AADTT less than 100.

Drivability Life supports multiple treatment options and the pavement management system recommends the optimal treatment based on the budget.

The treatment types shown in Table 4.2 are based on the averages of the 20-year predictive analysis and project recommendations from the DL system. The definitions for each of the treatment types are provided here.

- A chip seal treatment is a layer of emulsion and fine-graded aggregate that seals the pavement surface from moisture penetration.
- An ultra-thin overlay is an asphalt overlay that does not exceed 1.5 inches in thickness; this type of overlay addresses rutting better than a chip seal treatment.
- Preventive maintenance activities are thin functional treatments 1 to 1.5 inches in thickness or less, intended to extend the life of the highway by maintaining the driving surface.

- Minor rehabilitation activities consist of moderate pavement treatments that improve the structural life of the highway. A minimum design life of 10 years for asphalt pavements and concrete pavements is used for these projects.
- Major rehabilitation activities are heavy-duty pavement treatments that improve the structural life of the highway. A minimum design life of 10 years for asphalt pavements and 10 or 20 years for concrete pavements is used for these projects.
- Reconstruction is the complete removal, redesign, and replacement of the pavement structure (asphalt or concrete) from subgrade to surface. A minimum design life of 20 years for asphalt pavements and 30 years for concrete pavements is used for these projects.

Table 4.2 Pavement Treatment Types

Category	Chip Seal	Ultra-Thin	Preventive Maintenance	Minor Rehab	Major Rehab	Recon-struction	Total Investment
Interstate	N/A	N/A	2%	9%	3%	5%	19%
High volume	N/A	N/A	3%	14%	9%	15%	42%
Medium volume	7%	9%	0%	13%	N/A	N/A	29%
Low volume	5%	6%	N/A	N/A	N/A	N/A	10%

4.4 SUMMARY

Traditionally, CDOT has identified performance targets that reflect a desired state of performance for each of the major asset classes. Unfortunately, with limited resources it may not be possible to achieve these targets indefinitely across all asset classes. Therefore a distinction has been made in this document between these "**aspirational targets**" versus "**fiscally constrained targets**" which are achievable with constrained resources. The gap between these two types of targets is defined as the **"performance gap."** The recognition of the difference between aspirational and fiscally constrained targets will enable CDOT to better manage the balance between resources and achievable performance across assets.

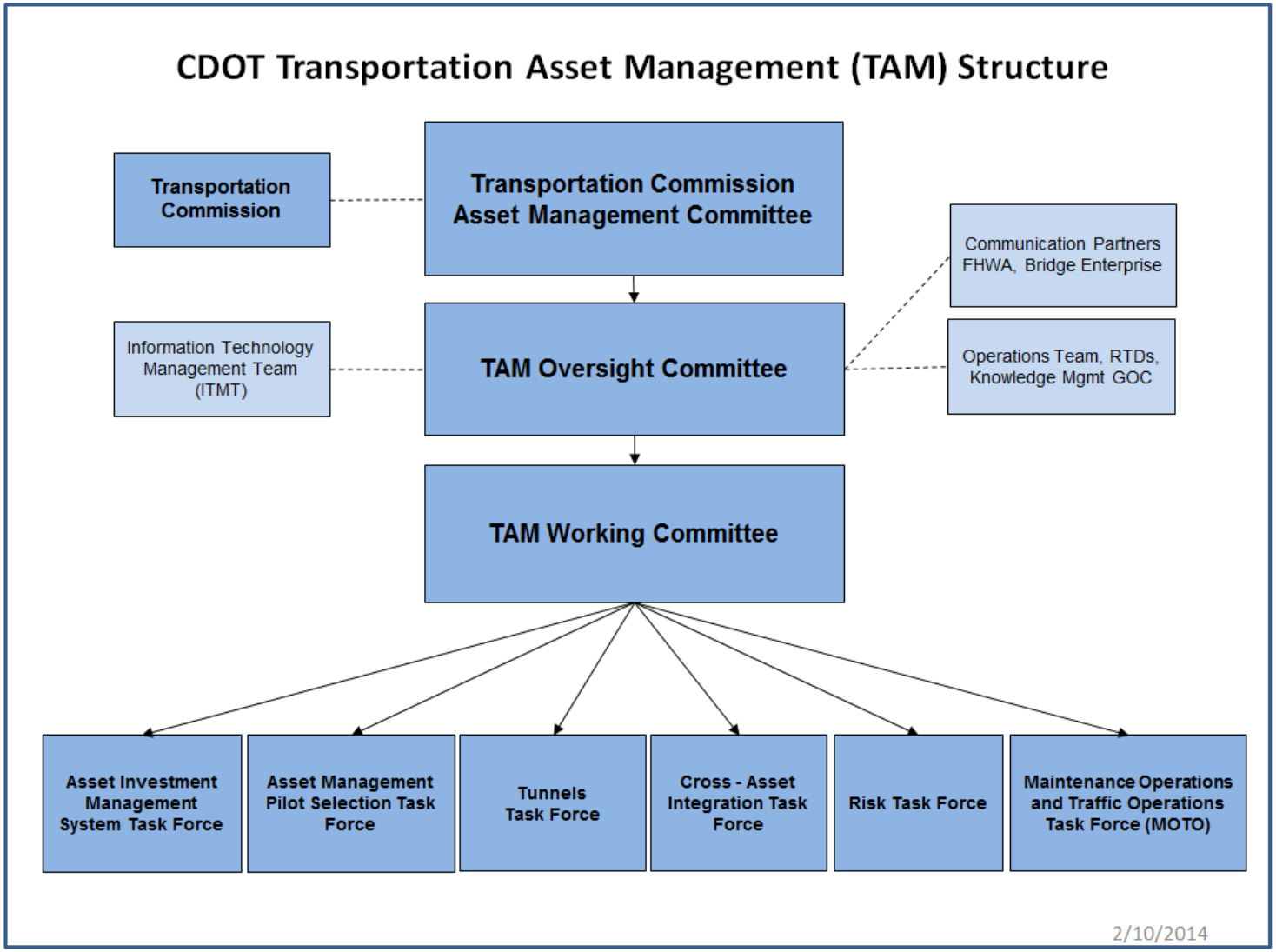
5.0 Current Asset Management Processes

This section describes important processes relevant to asset management at CDOT. These include:

- **The Annual Budget Process –** This is the process used by CDOT to distribute available funds between program areas for its annual budget.
- **Program Distribution –** This is the process used by CDOT during the Statewide planning process to discuss the potential allocations of available funds between program areas, over the long term. It was formerly referred to as resource allocation.
- **Planning Budget and Project Selection Processes –** These processes, which vary by asset, are used by CDOT to provide regions with planning budgets and to select specific treatments and projects.
- **The RAMP Process –** This process is used by CDOT to enhance the asset management program through CDOT's Responsible Acceleration of Maintenance and Partnerships (RAMP) program, which is described below.
- **Other Related Processes –** These processes include other activities that influence how asset management funding is distributed. Examples include the statewide planning process and CDOT's strategic planning process in which the agency mission and objectives are updated. The Office of Cash Management has recently been established, which will ensure that funds are available for asset management projects when they are ready to begin.

The organizational structure supporting Asset Management at CDOT is that of an Oversight Committee and a Working Committee. The TAM Oversight Committee consists of the Chief Engineer, the Chief Financial Officer, Division and Regional Directors. The TAM Working Committee includes asset managers, region staff, and others. The TAM structure chart is shown below, listing the names of those staff involved in TAM on a regular basis. CDOT has advanced significantly in the last year due to their efforts, which include providing the information included in this document.

Figure 5.1 CDOT Transportation Asset Management Organizational Structure



Source: CDOT

5.1 ANNUAL BUDGETING PROCESS

The annual budgeting process is a core part of the asset management planning process, in which funds are allocated to CDOT's programs. To the extent that this process relates to asset management, this process is detailed here:

- CDOT has formalized a process referred to internally as the "Delphi" process. Using the Delphi consensus building technique, CDOT brings together asset managers, budget staff, senior management, and region staff for a workshop to develop the staff recommendations on the asset management budgets for the upcoming fiscal year (FY). The CDOT Delphi process is described in this section.
- Projection of funding availability is required by the Regions more than a year in advance due to the design timeframes needed for successful program and project delivery.
- Prior to the Delphi workshop, staff ensures each asset manager is using the same assumptions for 20-year performance curve budget scenarios for each asset. For example, make assumptions clear – e.g., 3 percent annual inflation rate, 3 percent discount rate, and 0 percent revenue growth.
- Staff review the (current) FY 2014 Baseline budget and FY 0214 RAMP distributions to assets. Staff considers the PD 14 goals for Pavement, Bridge, and MLOS; these are set by the Transportation Commission with input from the Statewide Transportation Advisory Committee, and provide guidance on the performance they expect from the Colorado transportation system.
- During the Delphi workshop attendees are informed of the asset distributions in the previous fiscal year for comparison.
- Asset managers present available information on the projects and funds spent in the previous year.
- Asset managers consider risk where appropriate in their analysis. In the past asset managers have worked with the regions to identify and mitigate risks at the project level. Going forward asset managers are also being encouraged to incorporate a risk analysis at the program level (see Figure 11.6). While the Transportation Commission has and continues to have a Contingency Fund for use during emergencies, CDOT is also discussing the possibility of a fund specifically for proactive risk mitigation activities.
- Asset managers use CDOT's Asset Investment Management System (AIMS) to present their program performance versus investment levels, and make their case for funding to workshop attendees. (Examples of these types of performance versus funding curves are provided in Section 4.2.) The asset managers demonstrate the need for their asset and justify their funding request for that fiscal year.

- Consensus is achieved in distributing the limited pool of funds, as staff share why they voted the way they did, and asset managers provide comments.

For the FY 2015 Delphi Workshop, the participating asset classes consisted of Pavement, Bridge, Maintenance Levels of Service, Buildings, ITS, Fleet, Tunnels, Culverts, and Rockfall. These are the same assets that participated in the FY 2014 Delphi Workshop, which focused only on RAMP asset management funds.

Thirty-one staff members attended the FY 2015 Delphi workshop and they voted on the funding distributions to each asset. Staff included members of senior management, all of the regional directors, asset managers, and additional regional and headquarters staff. After all of the presentations, attendees voted for how they would distribute the budget. For each asset area, the voter with the highest and lowest amount for each asset was queried to explain, and then a second and final round of voting occurred. Six rounds of voting took place, two rounds for the Baseline Budget and two rounds each for RAMP funding, first at $150 million and then at $165 million, based on direction from CDOT's Executive Director. The second round votes became the staff recommendations to the Transportation Commission on the FY 2015 Budget and RAMP dollars. These are presented in Figure 5.2.

Figure 5.3 shows subsequent changes that were made based on discussion by the Transportation Commission and an updated revenue forecasts. Upon final approval by the Transportation Commission, the distributions will become part of the FY 2015 CDOT budget.

Figure 5.2 CDOT Staff Recommendations from the FY 2015 Delphi Workshop

CDOT Delphi Workshop for FY15 Asset Management:									
(In Millions)	FY14 Baseline Budget	FY15 Baseline Amount Requested	FY15 Final Baseline Budget:	FY14 RAMP Funding (RAMP at $160M)	FY15 RAMP Amount Requested	Delphi RAMP $150M Average:	FY15 Total With RAMP @$150M	Delphi RAMP $165M Average:	FY15 Total With RAMP @$165M
Surface Treatment	$150.6	$152.0	$149.5	$88.2	$88.0	$81.6	$231.1	$85.7	$235.2
Bridge, BE & Bridge Fixed Costs	$140.6	$151.6	$135.0	$33.3	$33.0	$26.2	$161.2	$28.7	$163.7
MLOS	$249.0	$256.5	$253.1	$0.0	$0.0	$0.0	$253.1	$0.0	$253.1
Road Equipment	$14.1	$14.6	$14.0	$6.8	$7.0	$5.7	$19.7	$6.9	$20.9
ITS	$11.2	$15.7	$11.6	$10.3	$22.0	$10.7	$22.3	$12.8	$24.4
Rockfall	$5.2	$5.2	$5.1	$3.8	$3.8	$3.6	$8.7	$4.0	$9.1
Buildings & Buildings COPs	$6.9	$11.6	$9.6	$4.4	$13.5	$9.8	$19.4	$11.2	$20.8
Tunnels	$0.0	$1.5	$1.5	$7.4	$11.4	$8.2	$9.7	$9.9	$11.4
Culverts	$5.6	$3.0	$3.6	$5.9	$7.6	$4.4	$8.0	$6.0	$9.6
Walls	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Total	$583.2	$611.7	$583.0	$160.1	$186.3	$150.2	$733.2	$165.2	$748.2

Note: A risk mitigation pool, designed to proactively mitigate risk based on pre-determined criteria and a scoring system, was discussed as part of the workshop, and will be revisited at the FY16 Workshop.

Source: CDOT

Figure 5.3 CDOT Staff Recommendations from the FY 2015 Delphi Workshop, with Subsequent Modifications

CDOT Delphi Workshop for FY15 Asset Management:

(In Millions)	FY14 Baseline Budget	FY15 Baseline Amount Requested	FY15 Delphi Baseline Budget:	*Adjustments by TC*	*Adjustment for updated BE Revenue Projection*	*Adjustment for MLOS Traf. Signal Asset Transfer to ITS*	Amount for FY15 Budget Recommendation to TC	FY14 RAMP Funding (RAMP at $160M)	FY15 RAMP Amount Requested	Delphi RAMP $165M Average:	FY15 Total With RAMP @$165M
Surface Treatment	$150.6	$152.0	$149.5				$149.5	$88.2	$88.0	$85.7	$235.2
Bridge, BE & Bridge Fixed Costs	$140.6	$151.6	$135.0		$4.5		$139.5	$33.3	$33.0	$28.7	$168.2
MLOS	$249.0	$256.5	$253.1			-$1.8	$251.3	$0.0	$0.0	$0.0	$251.3
Road Equipment	$14.1	$14.6	$14.0				$14.0	$6.8	$7.0	$6.9	$20.9
ITS	$11.2	$15.7	$11.6	$1.4		$1.8	$14.8	$10.3	$22.0	$12.8	$27.6
Rockfall	$5.2	$5.2	$5.1				$5.1	$3.8	$3.8	$4.0	$9.1
Buildings & Buildings COPs	$6.9	$11.6	$9.6				$9.6	$4.4	$13.5	$11.2	$20.8
Tunnels	$0.0	$1.5	$1.5	$1.0			$2.5	$7.4	$11.4	$9.9	$12.4
Culverts	$5.6	$3.0	$3.6				$3.6	$5.9	$7.6	$6.0	$9.6
Walls	$0.0	$0.0	$0.0				$0.0	$0.0	$0.0	$0.0	$0.0
Total	$583.2	$611.7	$583.0	$2.4	$4.5		$589.9	$160.1	$186.3	$165.2	$755.1

Note: A risk mitigation pool, designed to proactively mitigate risk based on pre-determined criteria and a scoring system, was discussed as part of the workshop, and will be revisited at the FY16 Workshop.

Source: CDOT

5.2 PROGRAM DISTRIBUTION FOR ASSET MANAGEMENT

The Program Distribution process is one part of the Statewide Planning process, which occurs every four years in line with Federal statutes 23 CFR 450 and 23 U.S.C. 135. Based on CDOT's Revenue Model, revenues are forecasted for more than the next 20 years. CDOT provides local planning organizations with realistic baseline, high, and low scenarios for planning purposes that are used in developing their Regional Transportation Plans (RTP). As required by state statute, RTPs must be fiscally constrained.

Regional Transportation Plans identify transportation issues and goals for each geographic area. Typically, priority corridors are identified and strategies are selected for associated improvements. Pavement, Bridge, and Maintenance have been managed through asset management programs for a number of years, but CDOT is now conducting a more integrated, fiscally constrained approach to identifying performance targets and associated funding levels in these areas. These performance targets and their associated funding levels have been developed in adherence with MAP-21. In order to provide a 10-year fiscally constrained forecast of funding for asset management, CDOT has made several assumptions. The assumptions and results of this effort are presented in the Financial Plan section of the RB AMP (Section 8.0).

5.3 RESPONSIBLE ACCELERATION OF MAINTENANCE AND PARTNERSHIPS (RAMP) PROCESS

In December 2012, CDOT announced a change it how it manages funds for transportation projects. The resulting change in budgeting practices provided CDOT with an opportunity to fund a one-time increase in project construction. The identification and selection of projects for these funds is referred to as Responsible Acceleration of Maintenance and Partnerships (RAMP), and it increased the amount of funds available for asset management. (For more information on the RAMP program, refer to Section 8.2.)

As an interim process while asset class predictive models are being developed, CDOT distributes RAMP funds via the Delphi workshop process used in the annual budgeting process, which requires the use of an asset management plan or model. The first round of voting is limited to the baseline budget and the rest of the rounds of voting are related to RAMP funds. For the FY 2015 Delphi workshop, RAMP funds were voted on at two funding levels, and eventually the funding level was determined and that distribution moved forward. In order to request RAMP Asset Management funds, asset managers must be able to meet the four RAMP Asset Management Eligibility Criteria:

1. Be able to demonstrate with a quantified performance measure the benefit of additional investment.
2. Have an existing asset management system that has, among other features, the ability to establish a performance target (e.g., maximize life cycle otherwise optimize performance) and at the same time minimize cost in achieving that performance target.
3. Distinguish between annual maintenance activities and capital preservation, and replacement activities, and fund only capital preservation and replacement. Crack filling and data gathering, for example, are not RAMP-eligible activities. Those should be addressed through the baseline budget setting process.
4. Be able to expend its RAMP funding by the December following the fiscal year of advancement. Fiscal Year 2014 RAMP must be spent by December 2014.

The assets considered eligible for RAMP funds for the FY 2014 and FY 2015 Delphi workshops were: pavement, bridge, fleet, ITS, tunnels, culverts, rockfall mitigation, and buildings. Maintenance Levels of Service (MLOS) and walls are working on establishing asset management systems and then they may decide to request RAMP funds in FY 2016 or FY 2017.

5.4 Regional Planning Budgets and Project Selection Processes

This section describes how CDOT establishes program-level funding for its Regions, and how it funds specific projects. These processes vary by asset type, as described below:

Pavement

Headquarters staff runs a statewide pavement analysis to optimize treatments to segments over many years for the entire pavement system. That statewide analysis generates a list of recommended statewide project segments. The cost associated with all recommended work in each Region is totaled and used to determine the percentage of the statewide surface treatment budget directed by the PMS to each Region. Those percentages are used to establish statewide planning budget distributions per Chief Engineer Policy Memo (PM) 19.

The planning budgets assigned to each Region are then used to run a second more refined PMS project analysis in each Region to generate a specific regional PMS list of recommendations. Chief Engineer Policy Memo 10 states that a minimum of 70 percent of surface treatment projects shall match model recommendations. Chief Engineer Policy Memo 7 constrains surface treatment funding expenditures to bid items that are deemed essential to improving pavement surface condition. Policy Memo 18 details preventive maintenance

requirements. The Pavement Design Manual establishes the allowed treatment types for each traffic-based pavement category. All of these controlling documents establish rules to be satisfied during the regional planning process. The goal of the regional planning process is a three- to five-year surface treatment plan. The regional planning over this longer period facilitates the complex design, clearance, and delivery of construction projects.

All proposed projects from the regional planning process are gathered into a statewide portfolio for the Surface Treatment Program. Before the surface treatment portfolio is finalized, the proposed list of construction projects and the PMS-recommended project locations are reviewed by headquarters staff to ensure that at least 70 percent of the statewide projects match. Budgeting of individual approved projects is made from a single statewide surface treatment pool.

There are also funds assigned to pavement maintenance activities as part of the Maintenance Levels of Service program (MPA 150).

Bridge

While there are no policy memos directly related to the bridge funding process, the current "Delphi" method of determining staff recommendations for base budget and RAMP funding requires CDOT bridge staff to present and defend the bridge funding needs. The base budget funding need is based on:

- Colorado Bridge Enterprise (CBE) annual revenue going to bridge replacement and major rehabilitation;
- CBE debt service;
- Anticipated inspection budget;
- Anticipated annual rate of bridges that require essential repairs;
- Estimated need to mitigate the risk exposed by scour critical bridges;
- Estimated need to replace the bridges with the lowest vertical clearance and numerous historical impacts; and
- Estimated need to replace the most restrictive of the load restricted bridges.

The RAMP advance funding for bridges is based on addressing the preventative maintenance backlog over the five-year period of RAMP.

Historically, bridge program funding was allocated to the regions based on the percentage of bridge deck area on the Select List (Poor and Fair bridges) less high-cost bridges and a minimum of five percent to any region. The regions then selected eligible bridges from the Select List for projects. Beginning in 2013, the asset management system identifies good candidates for replacement, repair, rehabilitation and preservation based on the optimal investment strategy. Staff bridge reviews candidate structures with regional staff, who consider their

resources, schedule and local input. This collaboration results in the programmed projects.

The Colorado Bridge Enterprise (CBE) was formed in 2009 as part of the FASTER (Funding Advancement for Surface Transportation and Economic Recovery) legislation. The purpose of the CBE is to finance, repair, reconstruct, and replace bridges rated Poor. It operates as a government-owned business within CDOT. The Colorado Transportation Commission serves as the CBE Board. Because the funding provided to CBE is not sufficient to address all the bridges in "Poor" condition or expected to drop into "Poor" condition in the future, the CBE developed a bridge prioritization system in order to address the highest priority bridges first. The CBE Prioritization Plan is a tool to aid decision-makers in establishing which projects are best suited to be programmed by meeting CDOT's and Bridge Enterprise's goals. The process is a means to help generally prioritize and rank structures in order of importance based on the quantitative and qualitative factors. The prioritization plan converts these factors for each structure to weighted numerical values. The combination of factors will determine a final score for each structure. These scores rank structures in the program in a consistent method and help the Bridge Enterprise assign resources in a more effective, transparent manner. The factors considered are described in Appendix D. The CBE is expected to continue to exist so long as the Colorado FASTER legislation remains in effect.

RAMP funding, which began with FY 2014 and is expected to last five years, is utilized for addressing the bridge preventative maintenance backlog. RAMP funds are assigned to the structure and transferred to the region once projects are selected that meet the preventative maintenance mandate of RAMP.

Maintenance

Funds are distributed via the MLOS budgeting system, based on performance-based budgeting. Based on how a Maintenance Program Area (MPA) has performed, the system reviews the costs, the available budget, and the expected cost to meet performance targets. Then the required amounts for the MPA are calculated. The statewide budget is set by the MLOS system for the nine Maintenance Program Areas across 14 sections.

The MLOS system also has the ability to generate the cost to achieve the desired overall grade for every MPA and for every section.

Buildings

Each Region completes its set of building inventory ratings on an annual basis. The building ratings are entered into SAP. The Region selects its top priority projects based on the inventory ratings and collaborates with the Property Management staff at headquarters to synthesize the list and determine the top priorities statewide. Property Management then determines how many of the

projects can be completed with the annual budget; completing the top priority projects first.

Annual Region planning budgets for controlled (A-C buildings) and deferred (D buildings) funds take into consideration employee safety, systems replacement, and preventative maintenance in addition to modifications and space realignment to accommodate employment shifts. This is an annual collaborative interaction between the Property Management Program Manager and the Region Maintenance Superintendents.

ITS Equipment

Each year requests are sought from CDOT Regions regarding their needs for maintaining devices or acquiring new devices. This list received is compared against condition of a device requested for replacement, including age, software/ hardware considerations, down time, past maintenance costs, regulatory requirements, etc. For new device requests, traffic issues and potential results are considered by implementing the device requested. Finally, selecting equipment or a regional request is considered with regard to project cost, available funds, need, and likely benefits.

Other considerations used in selecting ITS projects or strategies include:

- Federal guidelines such as MAP-21; and
- CDOT policies and changing objectives.

Fleet

In the past, the oldest and most used vehicles were prioritized the highest and then replacements were considered on the equipment plan until all FY dollars are spent. CDOT is working to improve the prioritization process by including functional obsolescence in the analysis, and eventually a net present value analysis of replacing versus maintaining equipment.

Funds for Road Equipment can be distributed from RAMP, CMAQ, Safety, Snow and Ice, and from the Transportation Commission contingency fund. On occasion safety trucks are purchased (i.e., signs, attenuators) through specific Commission funding requests. With CMAQ funding, the regions can buy a piece of equipment (brooms, mag chloride tankers) to treat the roads better and cut down on congestion, and improve air quality. Worn and damaged parts, plows and attachments (called "allieds") on snowplows can be bought/replaced using Snow and Ice funds. RAMP allows for additional capital purchases based on the asset management principles and the established equipment list.

Rockfall Mitigation Sites

Rockfall mitigation projects are identified and selected by corridor and "high-risk outlier" rank. Funding needs are estimated through a feasibility and design study and transferred accordingly to Region Rockfall Mitigation Pools.

Other priorities for allocating rockfall funds are in response to emergencies and urgent needs. Rockfall funding is distributed for rock scaling and other mitigation in situations where an imminent threat exists as determined by Rockfall personnel and in some cases Maintenance personnel with confirmation by Rockfall personnel. Rockfall mitigation device repairs and replacement are another funding priority. Rockfall fences are repaired or replaced as needed in response to rockfall impacts. These processes are reactive by nature as the timing of a rockfall occurrence is not predictable at this time.

Tunnels

Tunnels have had limited funding options in the past, and when an issue arose the Region Transportation Directors (RTD) would request funds from the Transportation Commission Contingency fund. Now that there is a focus on asset management, the Maintenance Superintendents for the tunnels are working with the Bridge Engineer to identify specific systems projects that require attention and are requesting funds during the Delphi workshops. The Tunnels Task Force meets as needed, and is convening this fall to discuss what asset management systems for tunnels include and how best to project future funding needs.

Culverts

The current "Delphi" method of determining staff recommendations for the baseline budget and RAMP funding requires Staff Bridge to present and defend the culvert funding needs. The baseline budget funding need is based on the anticipated annual rate of culverts that receive an Essential Repair Finding (ERF). The RAMP advance funding for culverts is based on eliminating the ERF critical culvert funding backlog over the period of the RAMP program and tiered in the priority order of Interstate, Non-Interstate National Highway System (NHS), and Non-NHS.

Historically, the allocations to the regions for culvert repair were based on the percent of culvert area or culvert length with ERF in each region. The first year of RAMP funding followed the same funding distribution process. In the future, the regions will receive a planning budget that aligns with where the asset that needs the funding exists, and will be tiered in the priority order of Interstate, Non-Interstate NHS, and Non-NHS.

5.5 TYING TOGETHER ALL TAM-RELATED PROCESSES

An important part of asset management is to link together an agency's various planning and decision-making processes. These processes include:

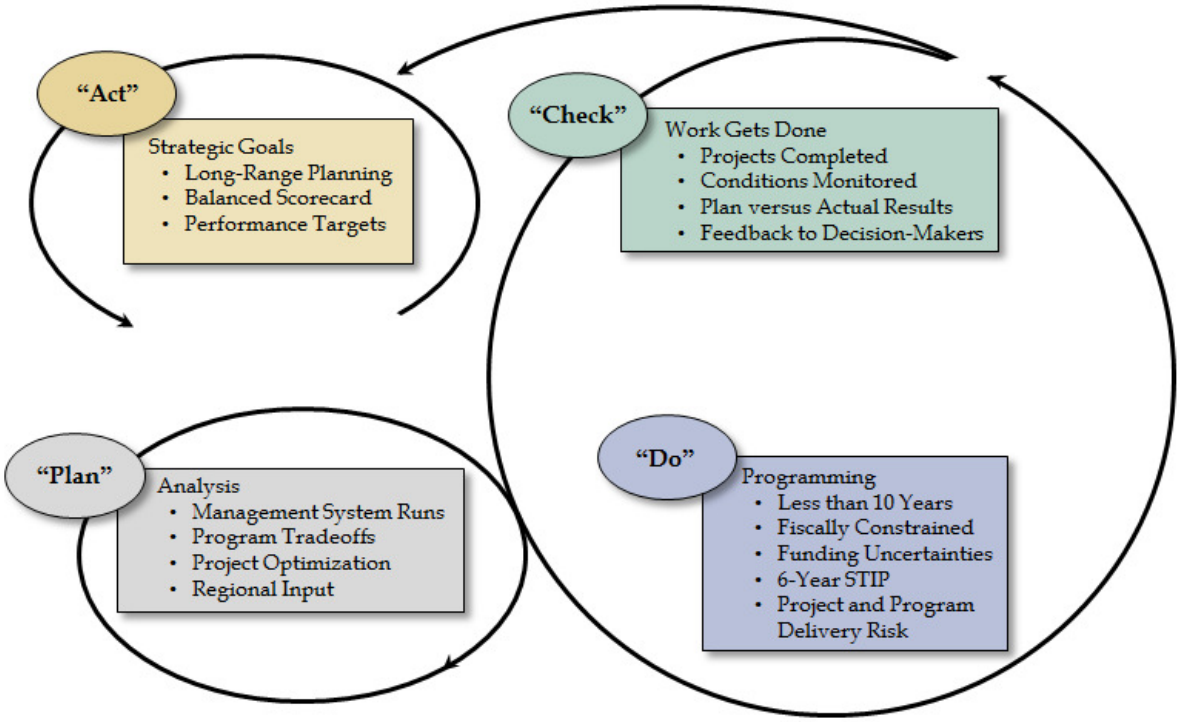
- Developing departmental policy directives, including Vision and Mission statements;
- Conducting public surveys (described in Section 2.0);
- Statewide transportation planning, including the development of corridor plans and long-term goals;
- Developing traffic growth projections (described in Section 2.0);
- Allocating funds between programs and regions (described above) and developing capabilities for cross-asset funding decisions;
- Selecting projects (described above);
- Project scoping and analyzing life-cycle cost considerations (described in Section 6.0);
- Risk management (described in Section 7.0);
- Financial planning, including projecting revenues and projected inflation rates (described in Section 8.0); and
- Considering investment strategies (described in Section 9.0).

More important than simply "linking" together the department's processes is to understand how asset management can be supported by these various processes, since each of these elements is important and related to asset management. Therefore, it is necessary to define how they all contribute and work together in best accomplishing the goals of asset management.

Strategic Management Framework

In order to fully utilize all of the pertinent asset management processes, a strategic management framework is necessary. A systematic method of bringing these capabilities together is important, in establishing an effective and repeatable means of managing assets. CDOT has chosen a "Plan, Do, Check, Act" (PDCA) approach as the organizing framework for asset management. The following phases of this framework, shown in Figure 5.4, explain how various CDOT planning and decision-making processes fit into the overall framework.

Figure 5.4 TAM Strategic Management Framework
Plan, Do, Check, Act



- **Plan –** The **"Plan"** phase focuses on defining an optimized set of projects and determining when they should be scheduled for delivery. CDOT's Asset Investment Management system provides decision-makers with performance information based on various levels of funding for each program. This allows the agency to tradeoff various investment levels across assets, and make funding distributions. The Financial Plan then defines budgets per asset, by year. Once a budget has been defined, specific projects are selected.
- **Do –** The **"Do"** phase is where projects are programmed, designed, and built. This phase begins by updating the State Transportation Improvement Program (STIP). A major objective during the "Do" phase is to minimize the risks of project delivery and strive to deliver projects on time and as originally intended.
- **Check –** The **"Check"** phase focuses on gathering and examining "feedback" on a continuous basis. This phase tracks the health of the network and determines how well previous plans have worked. The effort is based on information provided by the asset managers and regions, and enables a better understanding of the cause-and-effect between investments and results, including the feasibility of the latest set of performance targets. This understanding enables the agency to adjust its targets and strategies for the future. Ultimately, this insight will result in increased effectiveness

throughout the overall process and increased confidence in decision-making, leading to continuous improvement.

- **Act –** Information from the **"Check"** phase feeds into the **"Act"** phase, where CDOT determines its strategic priorities and sets new strategic directions based on strategic and statewide plans and a thorough analysis of performance trends relative to targets. This phase involves evaluating the gap between the desired function of future infrastructure and anticipated funding, in order to adjust targets and better focus available resources in the "Plan" phase. During this phase, decision-makers also assure that performance metrics are linked directly to stated goals of the department.

The "Plan, Do, Check, Act" process has been implemented successfully by numerous private- and public-sector agencies seeking to improve their management and decision-making processes. As the former Head of Planning for Royal Dutch/Shell, Arie De Geus, once said, "The only sustainable advantage an organization has is in its ability to self-scrutinize." Hence, the feedback of information, the self-scrutiny, and the learning that this framework will provide to CDOT will assure the highest possible level of asset management success and sustainability.

CDOT is currently implementing forms of all of the phases described above. In addition, it has identified several process enhancements for improving its asset management program over time. These enhancements are described in Section 11.0.

6.0 Life-Cycle Cost Considerations

This section describes how CDOT manages its assets throughout their whole life – from incept through retirement. Of primary interest is how CDOT approaches the objective of minimizing life-cycle costs in maintaining and replacing assets. As expected, the diversity of assets that CDOT owns dictates a range of analytical methods to understanding and optimizing these approaches across asset classes.

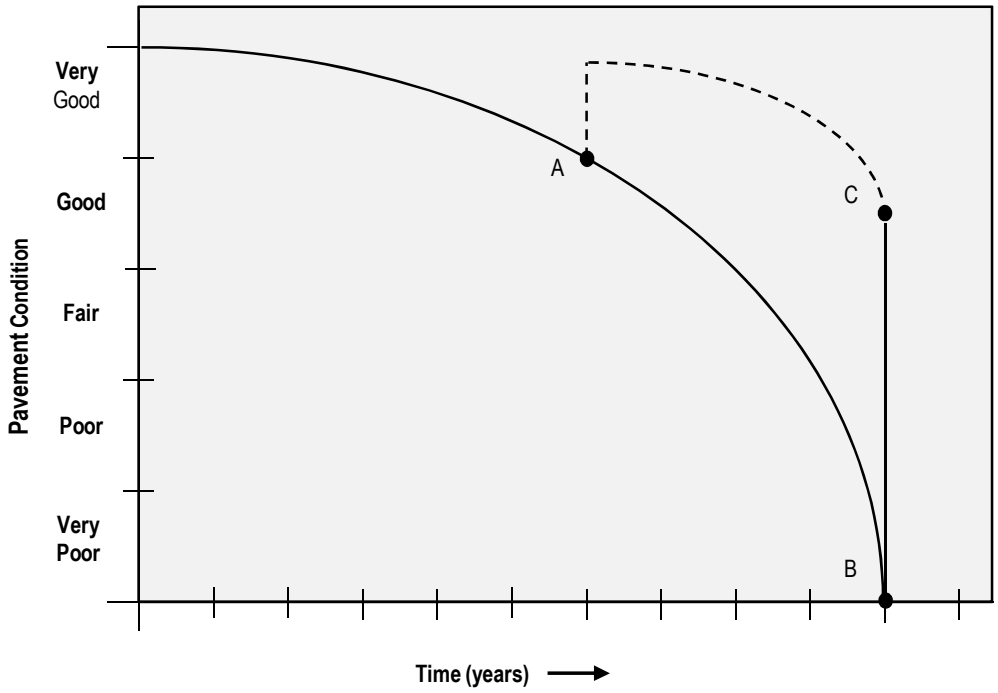
Generally, DOTs have accepted that a worst first approach to maintaining or replacing assets is not optimal. A worst first approach is one in which an agency ranks its assets from worst condition to best condition, and then works down the list until funds are expended. Most often, assets that are prioritized on a worst first basis require reconstruction or replacement, which is can be very costly relative to other types of maintenance and preservation activities.

A more cost-effective approach is to consider preventive maintenance activities and rehabilitation activities that stop short of asset replacement. A common example of a preventive maintenance activity is changing the oil in a car. A car owner who changes the oil in their car can significantly extend the life of their engine compared to an owner who performs no work until the engine seizes up, and requires replacement. Preventive maintenance and rehabilitation are designed to slow down the deterioration of an asset and to prolong its life. As an asset's life span is extended, expensive replacement can be pushed further into the future. As a result, preventive maintenance and rehabilitation strategies can drive down the overall cost of ownership.

Figure 6.1 provides a conceptual example of the benefits of a life-cycle cost approach to asset management. In this example, the solid blue line represents one option to maintaining an asset. The asset is built. It deteriorates to point B. Then work is performed, and its condition improves to point C. The dashed blue line represents a lower-cost alternative. In this option, work is performed when the asset reaches point A. At the end of the analysis period (point C), the asset is in the same condition as the first option. However working on the asset earlier its life cycle (point A) is less expensive than working on it once it has reached the end of its useful life (point B). This example illustrates how asset management involves the consideration of various combinations of maintenance and rehabilitation activities in order to minimize costs over the long run.

CDOT's approach to life-cycle cost management varies significantly by asset type. Each approach is described in the sections that follow. Additional details on specific investment strategies related to project identification and prioritization are provided in Section 10.0.

Figure 6.1 General Life-Cycle Cost Analysis Example



6.1 PAVEMENT

From a network perspective, CDOT's pavement management software performs a life-cycle analysis of various treatment strategies on each highway segment. The benefit of the life-cycle strategy (in years of drivability weighted by traffic volume) is balanced against the cost of the strategy (in net present value dollars). The program analyzes approximately 3,700 distinct pavement segments and compares preferred treatment strategies (those with the highest benefit/cost ratio) statewide. As the software models the deterioration of an individual segment, it identifies potential treatment options (minor rehabilitation, major rehabilitation, reconstruction, etc.) for that segment based on distresses (smoothness, rutting, and various cracking types) and DL.

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 DL score over the analysis period, and it includes a traffic-weighting factor that increases the benefit proportional to the amount of AADT on the highway segment. In this manner, treatments on highway segments with high volumes of traffic may take precedence over segments with low volumes. 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 benefit/cost 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 the course of a 20-year analysis. Assuming the average highway asset has 100 potential treatments or strategies, when all 3,700 segments are iteratively analyzed, the program will have 370,000 potential treatments identified. The software distributes dollars to the treatments with the highest-ranking benefit/cost ratio. The software will choose as many treatments from the list of 370,000 as allowed based on benefit/cost and available budget.

Recommendations from the pavement management software are provided to CDOT's regions, which then finalize which projects to implement. (This process is described in Section 5.4.) CDOT has a policy that at least 70 percent of pavement projects must match recommendations from this system. This policy helps to ensure that CDOT accounts for life-cycle cost considerations in its pavement program.

In addition, at the project level, detailed Life-Cycle Cost Analysis (LCCA) of specific treatment options on a pavement segment are mandatory on all paving projects with over $2 million in pavement construction cost. While the pavement management software identifies cost-effective treatment categories given site conditions and predictive pavement segment deterioration trends, the project-level LCCA process compares specific treatment options against each other, given detailed site conditions that include subsurface investigation.

Project-specific LCCA assess the salvage value of the pavements at the end of their projected life and incorporate that value into the LCCA. Each project design process includes cost comparison between remove-and-replace reconstruction methods and deep recycling reconstruction methods like cold in-place recycling, full depth reclamation, or rubbilization to deliver the optimal reconstruction method for pavements at the end of their structural life. These reconstruction project costs are tracked annually and become the actual treatment costs used for inputs into the pavement asset management system.

6.2 BRIDGE

Historically, CDOT has not used life-cycle cost (LCC) analysis directly when selecting bridge types or bridge preservation actions. Instead, structure type selection was based on lowest first cost, corridor requirements, or EIS/NEPA requirements. LCC was addressed indirectly however by incorporating activities that extended service life (e.g., integral abutment bridges to eliminate bridge joints, requiring waterproofing membrane under asphalt on bridge decks, sealing bridge decks at the time of original construction, etc.).

LCC is a new addition to the evaluation of bridge type selection and preservation action selection. The LCC requirement is motivated by MAP-21, the Colorado Transportation Commission (TC), and CDOT's Executive Director. The CDOT

Bridge Technical Memorandum defining the LCC requirement is in draft form but is in use on current projects at the preliminary design phase.

The primary effect of LCC on new bridge type selection is to identify the total LCC per service year in current dollars to preserve the structure for its design service life of 75 years, recognizing that not all components of the structure will last 75 years. The identified total LCC per service year is used to compare to other bridge type options before the preferred option is selected. The primary effect of LCC on preservation action selection is to identify the preservation actions that will have the largest reduction in LCC per service year by delaying the replacement cost to the latest but most appropriate year in the future.

When a bridge is replaced it is typically demolished and the contractor and subcontractors decide how to handle the materials. All steel and concrete is generally recycled.

6.3 MAINTENANCE

For some high-volume, lower-cost items maintained by a DOT it may actually be more cost-effective to simply replace them on an annual cycle rather than tracking them and replacing based on a life-cycle analysis. The traffic and safety assets within CDOT's maintenance organization include examples of these types of assets. CDOT replaces signs on a seven to 10-year cycle, while striping occurs annually. The Maintenance Operations Traffic Operations Task Force is currently reviewing the entire list of assets within its purview to determine which assets can be managed on a life-cycle basis and which should be replaced on a regular cycle or as needed.

6.4 BUILDINGS

Preventative maintenance can extend the life cycle of buildings and limit capital expenditures on replacement buildings. Every effort is made to complete preventative maintenance activities on buildings that will stop them from falling below the C-Level rating. Once a building falls into the D category it requires substantial rehabilitation and often replacement. Buildings with an overall score of "F" do not receive any controlled or deferred maintenance dollars, since they require replacement and it is not cost-effective to put some of the very limited maintenance dollars into buildings beyond repair.

6.5 ITS EQUIPMENT

Life-cycle considerations drive the replacement of many devices, including ITS. Data, including the acquisition date, manufacturer's expected life-cycle and maintenance costs are tracked for each device. However, although life cycle is an extremely important indicator as it pertains to ITS asset management, there are other important ITS data items that are also considered which provide greater

granularity regarding prioritization of asset management decisions and device condition. These include device functionality and device availability. Device functionality is defined by the ITS Branch as the primary purpose of the device and includes five functionality categories:

- **Regulatory –** Regulatory devices perform a regulatory function and are mandated. These include devices that support High-Occupancy Vehicle and Toll (HOV/HOT) lanes, chain laws for poor weather conditions in the mountains, variable speed limit signs, weigh-in-motion scales, and over-height detectors and lane use signs in the tunnels. Also included are all other devices in HOV/HOT corridors necessary to perform operations, such as Travel Time Indicators, radar, Closed Circuit television, gantries, and gates.
- **Safety –** The primary purpose of safety devices is to promote and support safety. This includes CCTV in the tunnels, radar/sign warning on curves, fog visibility and flood signs, weather stations, bridge spraying systems, call boxes, and other safety-related functions.
- **Mobility –** The primary purpose of these devices is to promote and support mobility. This includes TTI, radar, and ramp-metering devices along with signs used to provide real-time traveler information.
- **Data Support –** The primary purpose of these devices is to provide data that is not used in a real-time manner. An example of this kind of device is an Automatic Traffic Recorder (ATR), which provides data on traffic counts.
- **System Support –** The primary purpose of these devices is to support system operations such as network equipment, switcher, nodes, modems, encoders, decoders, servers, etc.

Together, these five categories are assessed along with age, life cycle and availability to prioritize maintenance and capital replacement activities.

Device availability is defined as the time the device was inoperable or the difference between the time when the device stopped operating and the time the device was repaired. This allows CDOT to determine percent of availability at a device level, device category level, corridor, and other geographic area and statewide system level.

6.6 FLEET

Previously, CDOT replaced vehicles based on a combination of age and usage. This approach is analogous to a "worst-first" approach. However, with the development of asset management, CDOT is now modifying this approach to incorporate the costs of maintenance and repair on vehicles. For those vehicles determined to have higher than expected maintenance costs staff is now discussing alternatives to replacing those vehicles. For example, a truck that is 25 years old and running just fine might be kept while an 18-year-old truck that needs major repair work consistently might be more cost-effective to replace. A

new report in CDOT's SAP financial system captures the actual cost of the vehicle repair over its life. The new report displays the potential maintenance costs versus the replacement cost to enable maintenance managers to make more informed recommendations to decision-makers.

6.7 TUNNELS

Tunnels are built with long life cycles. There are several unmanned tunnels in Colorado that were built in the 1800s. The focus for life-cycle analysis in Colorado is on the manned tunnels, which include heating, ventilation, and air conditioning (HVAC) systems, fire suppression, water treatment and other systems, each with life cycles of their own that can be costly to replace. CDOT staff at Eisenhower-Johnson Memorial Tunnel, Hanging Lake Tunnel and staff who work on the Wolf Creek Tunnel have been meeting regularly as part of the TAM Tunnels Task Force, in part to gain a better understanding of their asset replacement and related budgetary needs.

6.8 CULVERTS

Minor structures with Essential Repair Findings that are culverts are generally replaced when an inspection indicates that there is a safety concern (i.e., culvert collapse risk due to deterioration). Replacement can be accomplished by excavating through the overlying pavement, micro tunneling, pipe jacking, or a structural slip lining. The most cost-effective measure would be selected as part of the design process. Slip lining does require that the culvert has not begun to collapse and can also be considered a preservation, rehabilitation or repair action if the slip lining method chosen does not provide structural capacity. Hydraulic analysis is required as part of the design process to make sure the final culvert is properly sized because slip lining does reduce the size of the culvert. Replacement, preservation, rehabilitation or repair expenses have averaged about $370,000 per culvert.

6.9 ROCKFALL MITIGATION SITES

For many of the potential rockfall mitigation options, regular maintenance labor and expenditures are required. Therefore, the selection of rockfall mitigation should consider life-cycle costs and the level of maintenance commitment must be established in consensus with Region management. Maintenance activities needed include removal of debris behind barriers and fences, cleaning of shoulder ditches, patching of steel mesh on a steep slope, and repair of proprietary metal fence systems. If maintenance activities are not performed the service life of rockfall mitigation assets is greatly reduced, and the hazard level will increase. The lack of maintenance can potentially undermine the benefits of the rockfall improvements.

7.0 Incorporating Risk into the Asset Management Program

7.1 Overview of Risk Management Process

CDOT 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 a risk register in order to establish the risk management priorities across the department; and
3. A comprehensive decision-making process that includes risk assessment 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 risks – their probabilities and their potential consequences;
- Mitigation opportunities – defined in terms of their benefits and costs; and
- 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 a critical aspect. Therefore, risk opportunities are being quantified in terms of the probabilities and consequences of occurrences, and the benefits and costs of various mitigation strategies. Similar to performance-based assets, such as pavement treatment candidates, potential risk events can be evaluated and prioritized based on their benefit/cost ratios. 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. This is one proposed method CDOT is considering and it applies well to the portfolio approach to packaging risk-based opportunities, whether for site-specific efforts, corridor-based mitigation efforts, or regional and statewide maintenance activities.

The section describes the current status of risk management at CDOT. Future planned activates are describe in Section 11.0. It is important to note that risks outside the asset management program are more properly the subject of a general enterprise risk management framework and are not included as part of this RB AMP.

7.2 CURRENT PRACTICES

CDOT initiated several major steps during 2013 to support the implementation of risk management at the department. In February, asset managers and additional staff interested in risk were queried for their initial lists of potential risks that would impede CDOT from fulfilling its mission, focusing on underserved assets. A follow up exercise with the Transportation Asset Management Risk Task Force (a self-selected group of folks interested in risk at CDOT) identified a set of priority assets that provided a good starting point and enabled the group to more comprehensively brainstorm a full list of potential risks to CDOT. The development of a list of potential risks included estimated levels of potential consequences and likelihood, and considered following three levels of risk:

- **Agency (Strategic, Corporate) Risks –** Affects mission, vision, and overall results of the asset management program. Examples include politics, public perception, reputation, levels of available revenue, etc.
- **Programmatic (Business Line) Risks –** Affects 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 in general cause projects to be delayed. These causes are not related to any specific projects. Examples include project delivery risks, revenue uncertainties, cost-estimating processes, revenue and inflation projection inaccuracies, construction cost variations, materials price volatility, data quality, retirements, etc.
- **Project/Asset Risks –** Affects scope, cost, schedule, and quality of projects. In contrast to programmatic risks, project risks are related to specific projects. In other words, there is something particular to a given project that results in a project delay. Examples include hazardous materials, geology, environmental issues, right-of-way issues, utilities, project development timeline/delays, scope growth, cost overruns, project delays, etc.

The initial list of risk categories and individual risk types were reviewed with senior management. The objectives of this review were to obtain their views on the completeness of the list and capture any additions or deletions.

CDOT also conducted a workshop involving the Risk Task Force and subject matter experts in order to score the (updated) list of potential risk events. This effort documented probabilities (likelihood), consequences, and risk ratings, based on the rating system provided in Figure 7.1. The workshop also assured that the information generated was sufficient to populate a comprehensive risk register. The risk register that resulted from the workshop, shown in Table 7.1, was the final accomplishment of 2013 for implementing risk-based management into TAM.

Table 7.1 shows the risks identified by staff along with staff's determination of the likelihood of the event occurring, where 5 is High and 1 is Low. The risk was

then assessed by staff in terms of consequence, where 5 is Catastrophic and 1 is Negligible. If additional items were considered as part of the score they have a check in the Other Considerations section.

Figure 7.1 Risk Rating Scale

		Consequence (Level/Descriptor)				
Likelihood		1	2	3	4	5
Level	Descriptor	Negligible	Minor	Major	Critical	Catastrophic
1	Low	1	2	3	4	5
2	Medium Low	2	4	6	8	10
3	Medium	3	6	9	12	15
4	Medium High	4	8	12	16	20
5	High*	5	10	15	20	25

Source: CDOT

The risk register contains risks identified by staff for agency, program, and project-level risks. The methodology for determining the risk ranking was developed by a consultant through the course of workshops and meetings during March-September 2013. The risk score is calculated as follows:

Risk Score = Ps × Os × [(Ss + Ms + Ds + Fs)/4]

Where:

Ps = Likelihood Value;

Os = Other Considerations Value = 1 + (0.05 × [Number of Other Considerations Checked];

Ss = Safety Value;

Ms = Mobility Value;

Ds = Damage (Asset) Value; and

Fs = Financial Value.

The higher the Risk Score, the more important it is for CDOT to develop a risk mitigation strategy to deal with the risk (or formalize the existing strategy).

Table 7.1 Initial Risk Register

				Consequence Score				Other Considerations					
Risk ID	Voted Priority	Event/Occurrence	Likelihood	Safety	Mobility	Asset Damage	Other Financial Impact	Funding	Insurance	Regulatory	Political	Reputation	Risk Score
Agency Risks													
1a	11	Not having enough funds to meet targets due to inflation in construction costs	5	3	4	4	2	√		√	√		19.5
1b	4	Ability to meet MAP-21 targets for NHS segments under local control	5	3	2	3	2	√		√	√	√	15.0
1c	6	Revenue variations/uncertainties – inability to predict/project total funds available to CDOT	5	1	1	2	3	√	√		√	√	10.5
1d	9	Politics in general, combined with leadership changes in the Department	4	1	2	1	2	√	√	√	√	√	7.5
1e	9	Public perception of CDOT (Negative) – resulting in an inability to garner new funds	2	2	4	3	2	√			√	√	6.3
1f	11	Not communicating to and getting buy-in at the appropriate levels in CDOT how the RB AMP works	3	1	1	1	1	√			√	√	3.5
Program Risks													
2a	8	Unfunded maintenance requirements – e.g., regulatory	5	3	3	2	3	√		√		√	15.8
2b	9	Will I-70 viaduct pull funding from other projects	4	2	3	3	2	√	√		√	√	12.0
2d	9	Retirement of key people, loss or turn-over of staff, resulting in loss of critical knowledge	4	3	2	2	3				√	√	11.0
2e	9	Data management (that impacts ability of CDOT to document accomplishments)	5	1	2	2	3			√		√	11.0
2f	9	Project delivery risks due to organizational or systemic issues, e.g., communication, etc.	3	2	1	1	4	√	√		√	√	7.2

				Consequence Score				Other Considerations					
Risk ID	Voted Priority	Event/Occurrence	Likelihood	Safety	Mobility	Asset Damage	Other Financial Impact	Funding	Insurance	Regulatory	Political	Reputation	Risk Score
2g	8	Construction cost variations	3	1	1	2	4	√	√			√	6.9
Project Risks													
3a	10	Flooding (resulting in long-term impacts – damage to assets, requiring replacement)	4	5	5	5	5	√	√		√	√	24.0
3b	12	Burn area – post-fire debris flows, blocked culverts – loss of service	5	4	4	4	2	√	√		√	√	21.0
3c	11	Scour Critical Bridges are vulnerable to a storm event of sufficient size resulting in road loss	4	5	5	4	3		√			√	18.7
3d	10	Rockfall incident with loss of function/mobility (several days) or fatality	4	5	4	3	3	√	√		√	√	18.0
3e	11	Landslide – loss of road and mobility	4	4	4	4	2	√	√			√	16.1
3e2	9	Hazardous materials (need more of an event description) – spill, e.g., Hwy 6	5	3	2	4	2		√	√		√	15.8
3f	9	Retaining walls (failing and impacting traffic)	4	4	3	4	2	√	√			√	15.0
3g	9	Subsurface utilities impacts by others in ROW (and below roadways)	4	3	3	4	2		√		√	√	13.8
3h	11	Crash with fire occurs inside a tunnel resulting in a loss of service	3	4	4	4	3	√	√		√	√	13.5
3i	9	Overhead bridges are in danger of being hit – over height vehicles	5	3	3	2	1		√			√	12.4
3i2	10	ITS or traffic control failure – resulting in safety impact	5	4	2	1	1		√			√	11.0
3j	10	Avalanche causing delay	5	3	3	1	1		√			√	11.0
3j2	9	Bridge failure – structural, other than hits, scour, resulting in loss of service	2	5	5	4	4	√	√		√	√	10.8
3k	10	Avalanche requiring maintenance but no/minimal delay	5	3	2	1	1		√			√	9.6
3l	9	Culverts less than 48 inch diameter (failing and closing road – not managed currently)	3	3	3	3	2	√	√			√	9.5

				Consequence Score				Other Considerations					
Risk ID	Voted Priority	Event/Occurrence	Likelihood	Safety	Mobility	Asset Damage	Other Financial Impact	Funding	Insurance	Regulatory	Political	Reputation	Risk Score
3m	11	Project delay due to environmental, utility, RR, or right-of-way issues, or landowner claims	5	1	2	1	2			√	√	√	8.3
3m2	10	Rockfall incident requiring maintenance, but no or minimal mobility impact	5	2	1	2	1	√					7.9
3q	11	Landslide – maintenance required	5	1	1	3	1	√					7.9
3q2	9	All bridges that are in danger of being hit	3	3	3	2	1		√			√	7.4
3r	9	Scope growth	5	1	1	2	1	√	√			√	7.2
3v	9	Retaining walls (requiring maintenance but no mobility impacts)	5	1	1	2	1	√					6.6
3w	10	Tunnel collapse	1	5	5	5	4	√	√		√	√	5.7

This risk register was finalized on September 17, 2013 at a staff Risk Workshop. The next step for CDOT is to identify, evaluate and prioritize potential mitigation strategies for the highest priority risks. This activity is discussed in Section 11.3 as a future enhancement to the asset management process.

During September 9-15, 2013, Colorado experienced excessive rainfall leading to serious impacts to 17 counties. The risk of flooding had previously been identified as a high-priority risk in earlier meetings due to the flooding issues at wildfire locations throughout the State. The impact of the flooding resulting from rainfall over a large portion of the State reinforced staff's determination that flooding due to any cause can be a substantial risk to the transportation system. Additional work on managing systems work is discussed in Section 11.3 as a future enhancement.

8.0 Financial Plan

This section presents an asset management financial plan. The financial plan discusses historic funding levels and presents the level of funding expected to be distributed to CDOT's assets over the next 10 years.

The plan financial plan relies on outputs from the annual budget process, the program distribution process, and the RAMP process, all of which are described in Section 5.0. This section presents the results of these processes.

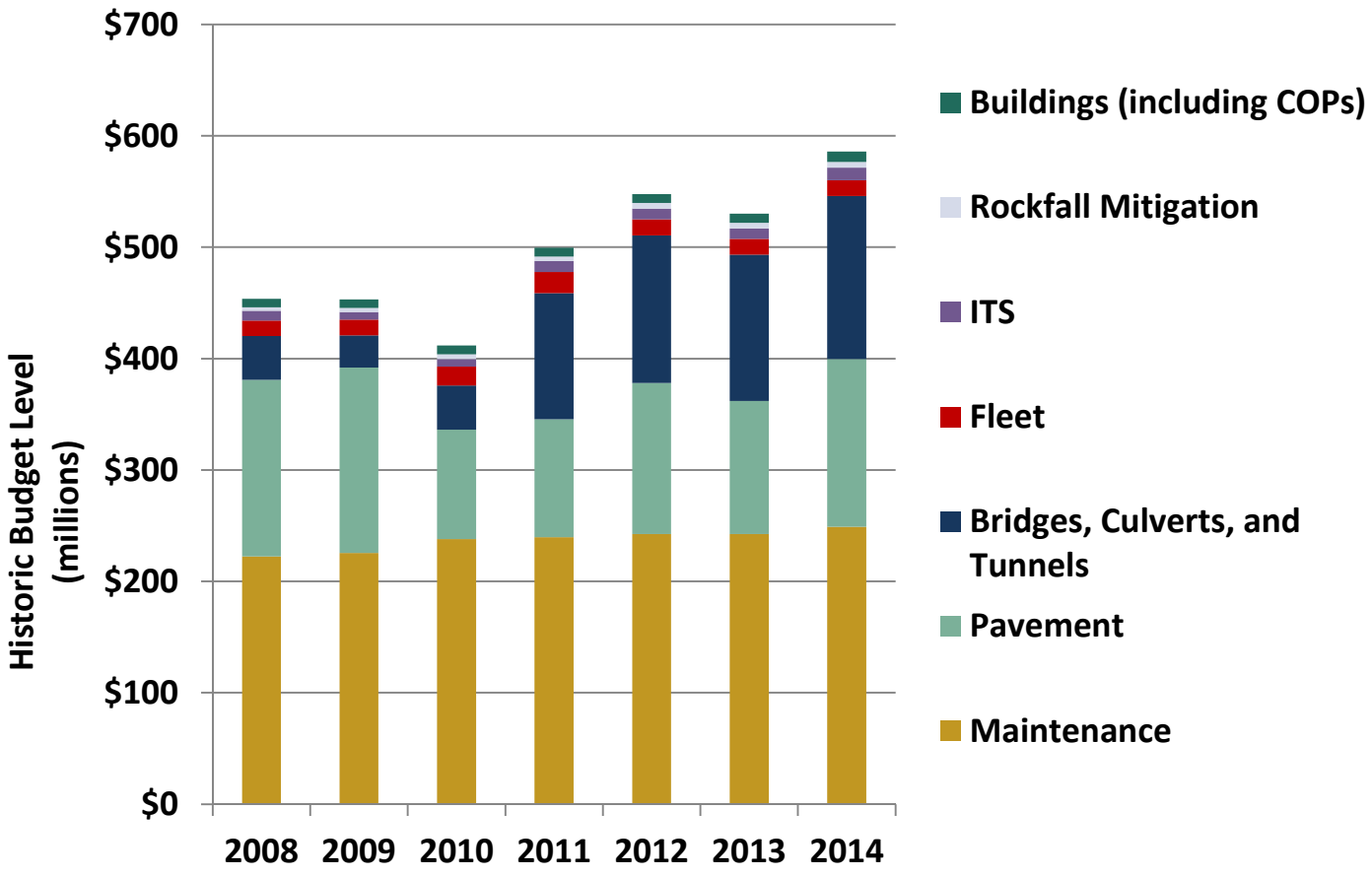
8.1 HISTORIC FUNDING LEVELS

CDOT's overall annual funding for the past 10 years has fluctuated between $800 million to $1.6 billion. Of that total, asset management activities have received approximately $450 to $630 million annually. The largest recipient of funds is Maintenance, which received on average $233 million during Fiscal Years 2008-2012. Approximately half of the funds dedicated to maintenance support the salaries of the maintenance personnel, which comprise almost 60 percent of the CDOT workforce.

Figure 8.1 shows historic funding levels by asset class per year After Maintenance, Pavement, and Bridge have received the most funding among the assets at CDOT. For the FY 2008 to 2012 time period, pavement received on average $152 million, while Bridge received on average $123 million. Of the total funds provided to asset management, over 80 percent is provided to these three asset areas. The remainder of the funds is distributed across the following areas:

- Fleet ($19 million per year, 5-year average);
- ITS ($12 million);
- Rockfall Mitigation ($5 million);
- Buildings ($9 million, less $2.1 million in COP Payments = Net of $6.9 million); and
- Tunnels, Culverts, and Walls, which historically were a part of the Bridge distribution.

Figure 8.1 Historic Budget Levels by Asset Class



Source: CDOT

8.2 REVENUE OVERVIEW

CDOT is financed by a variety of fees and taxes paid by the users of the State and national transportation systems. Sources of revenue include:[7]

- Motor fuel taxes.
  - The State of Colorado levies excise taxes on gasoline, diesel fuel, and special fuels used to propel motor vehicles and aircraft that use public highways and airport facilities.
  - The Federal government levies excise taxes on gasoline, diesel fuel, and all special fuels used to propel motor vehicles on public highways.
- Registration fees.
  - The State of Colorado levies a variety of fees and surcharges on motor vehicles registered to use public highways; however, one tax, the specific ownership tax, is credited to local property taxing subdivisions of state government rather than to a directly transportation-related use.
  - The Federal government charges annual weight-based taxes on heavy vehicles registered for interstate commerce.
- Other taxes.
  - The State of Colorado levies a sales tax on the value of aviation fuel sold in Colorado.
  - The Federal government levies a tax on the value of heavy commercial vehicle sales.
  - The Federal government levies a weight-based excise tax on tires exceeding 40 pounds.
- Other user fees.
  - The Colorado Department of Transportation generates revenue by selling oversize/overweight permits, access permits, bid plans, property, and excess right-of-way, and through the receipt of interest income derived from investment of cash.
- General purpose revenue.
  - Current law allows for a series of five years of conditional transfers of two percent of gross General Fund revenues to the Department; those transfers are dependent upon a personal income trigger being met. It is currently anticipated that the trigger will be met soon and that CDOT will begin receiving funds in Fiscal Year 2016.

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[7] CDOT Budget for Fiscal Year 2013-2014, April 19, 2013; supplemented by input from CDOT staff.

Two other important funding initiatives (the Bridge Enterprise and the RAMP program) are described in more detail below.

Bridge Enterprise Funding

On March 2, 2009, Colorado Senate Bill 09-108, Funding Advancement for Surface Transportation and Economic Recovery (FASTER) was signed into law. This legislation established a newly dedicated and sustainable funding source for transportation which continues to have a significant impact each year in providing funding for Colorado's bridges.

> The law increases revenues from various sources for transportation improvements. A portion of the funding designated as the "bridge safety surcharge" is dedicated specifically for Colorado's most deficient bridges – those bridges rated "poor" (Bridge Sufficiency Rating less than 50) by the Colorado Department of Transportation (CDOT). Revenues from the bridge safety surcharge have been phased in over a three-year period, and reached $102.2 million in the third year (State Fiscal Year 2012).
>
> To assist with this historic focus on Colorado's poor bridges, the legislation did more than simply authorize the Bridge Safety Surcharge. FASTER created a new enterprise, the Bridge Enterprise (BE), and designated the Transportation Commission to serve as the Bridge Enterprise Board of Directors (Board). The business purpose of the Enterprise is to "finance, repair, reconstruct, and replace any designated bridge in the State" per C.R.S. 43-4-805(2)(b). Because it was constituted as a government-owned business, the Enterprise may issue revenue bonds to accelerate construction of Colorado's poor bridges. On June 18, 2009, the Board officially approved the enactment of the bridge safety surcharge, as required by law. Bridge projects under the Enterprise may include the repair, replacement, or ongoing operation or maintenance, or any combination thereof, of a designated bridge.[8]

"There are currently a total of 87 bridges included within the $300 million bond program. These 87 bridges are included within (or a subset of) the total population of 167 FASTER eligible bridges."[9]

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[8] Colorado Bridge Enterprise 2012 Annual Report, January 14, 2013.

[9] Ibid.

Responsible Acceleration of Maintenance and Partnerships (RAMP) Program

In 2006, CDOT instituted a new Enterprise Resource Planning (ERP) computer software system. One of the reasons for doing so was to improve CDOT business and financial practices, including the potential opportunity to change the way CDOT budgets and expends funds. In a time of reduced resources, CDOT moved forward with this new approach to become more efficient and effective.

In December 2012, CDOT announced a change it how it budgets and expends funds for transportation projects. In the past CDOT did not advertise a project until all of the money was "in the bank," which means the department was saving money for projects over multiple years before construction began. In addition, some projects take several years to construct – so money often sat unspent when it could be utilized much sooner. Based on new cash management procedures, CDOT funds multiyear projects based on year of expenditure, rather than saving for the full amount of a project before construction begins. This change in budgeting practices has provided CDOT with a one-time opportunity to increase project construction by $300 million per year over the next five years. The identification and selection of projects for these funds is the RAMP program. RAMP consists of two programs: 1) Asset Management and Operational Improvements, and 2) Transportation Partnerships. The first program is dedicated to preserving the State's existing assets. The RAMP program has increased the overall amount of funding available for asset management for five years.

8.3 FUNDS EXPECTED TO BE AVAILABLE FOR ASSET MANAGEMENT

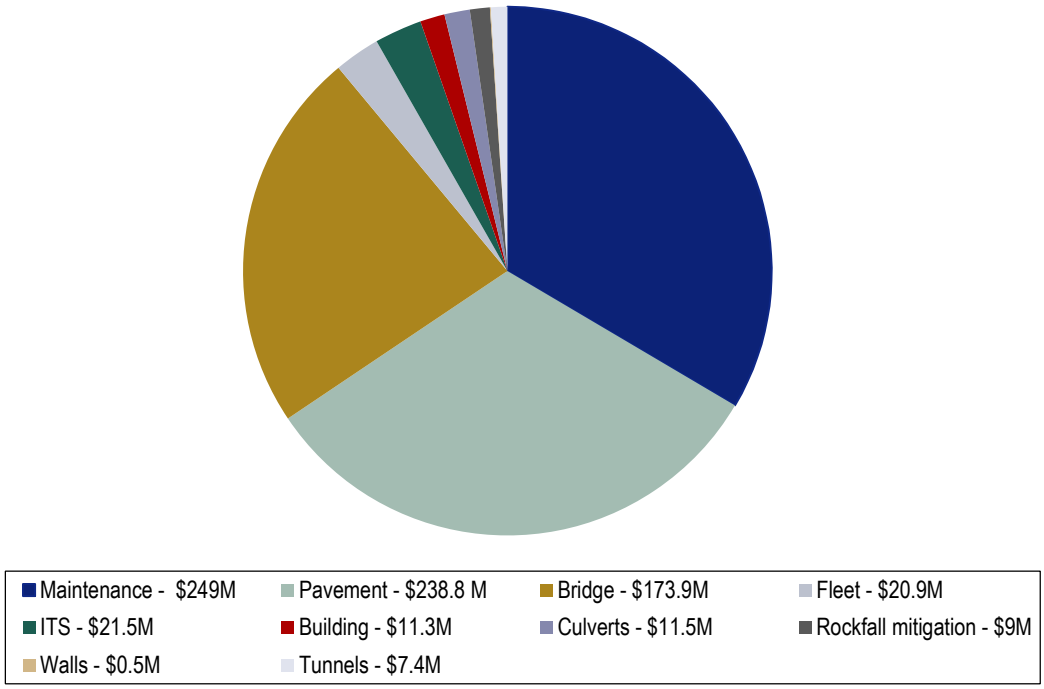
CDOT's total revenues for the current fiscal year (July 1, 2013-June 30, 2014) are estimated to be $1.1 billion. Of this amount, the FY 2014 baseline budget for asset management has been set at $583 million plus an additional $160 million from RAMP. These funds are illustrated in Figure 8.2.

The main sources for CDOT's total budget plus the RAMP program are:

- Colorado Highway Users Tax Fund (HUTF) – $502.9 million;
- Federal Highway Revenue, the Highway Trust Fund – $491.3 million;
- RAMP – $160 million; and
- Bridge Enterprise – $115.5 million.

It is important to note that RAMP is a temporary increase for five years.

Figure 8.2 FY 2014 Funds



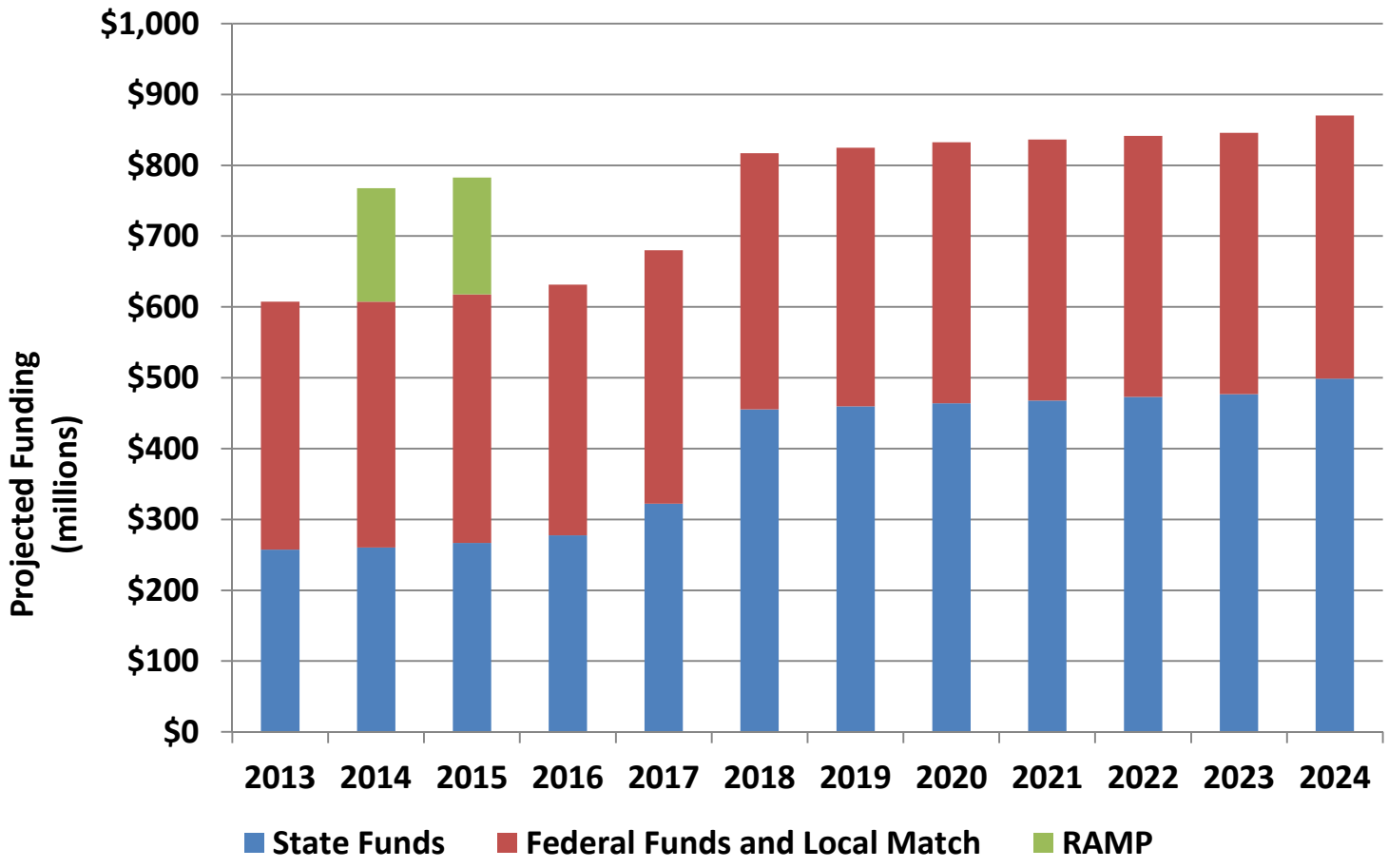
Source: CDOT

Figure 8.3 shows projections for asset management funding for the next 10 years. CDOT developed these projections by starting with the current fiscal year budget as a baseline, and then modifying it based on the following assumptions:

- As part of CDOT's Fiscal Year 2015 Delphi workshop (described in Section 5.1), CDOT's maintenance budget is expected to increase by three percent a year;
- As part of CDOT's Fiscal Year 2015 Delphi workshop, CDOT's pavement budget is expected to increase to $240 million per year; and
- The bridge budget has been increased to account for the latest Bridge Enterprise assumptions.

TRANS bond debt service will be retired in FY 2017, thereby decreasing a current financial commitment by $167 million annually beginning in FY 2018, allowing those funds to be spent elsewhere. These funds are shown to be allocated to Asset Management programs.

Figure 8.3 Projected Funding Potentially Available for Asset Management Including RAMP



Source: CDOT

8.4 FUTURE FUNDING LEVELS BY ASSET TYPE

Table 8.1 presents estimates for how CDOT's asset management funds will be distributed between its asset programs over the next 10 years. These estimates were developed by applying the results of the Fiscal Year 2015 Delphi workshop (described in Section 5.1), along with the Fiscal Year 2016 Delphi workshop and the revenue projections described in Section 8.3, in conjunction with direction from the Colorado Transportation Commission through the Statewide Planning process.

Based on the results of the Delphi workshops, CDOT's Maintenance budget is anticipated to increase by approximately three percent per year for at least 10 years and Pavement budget is expected to be increased to $240 million per year. Bridge funds have been adjusted to the latest estimated revenues for Bridge Enterprise. The rest of the assets remain mostly constant.

It is important to note that Delphi workshops provide staff recommendations to the Colorado Transportation Commission, which then makes all fiduciary decisions for CDOT and may approve budget figures that vary from the Delphi recommendations.

The funding amounts in Table 8.1 represent estimates. They rely on a combination of revenue projections and Delphi workshops, along with direction from the Transportation Commission, and are considered reasonable estimates. However, each subsequent Delphi workshop will consider updated revenue projections and the latest needs analysis by asset managers, and the planning budgets will be updated for each fiscal year to reflect the latest information.

CDOT is incorporating the funding amounts in Table 8.1 into the overall program distribution for the Statewide Plan. The Statewide Plan is currently in development and scheduled for adoption by the Colorado Transportation Commission in the summer of 2014.

Table 8.1 10 Year Asset Management Planned Funding

10 Year Estimate (Millions)	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Total CDOT Estimated Revenue	**$1,104.8**	**$1,110.8**	**$1,132.7**	**$1,099.2**	**$975.9**	**$981.4**	**$986.8**	**$974.6**	**$977.3**	**$978.9**
MLOS	$251.3	$254.4	$262.0	$269.9	$277.9	$286.3	$294.9	$303.8	$312.9	$322.3
Surface Treatment	$235.2	$235.9	$240.0	$240.0	$240.0	$240.0	$240.0	$240.0	$240.0	$240.0
Bridge	$53.3	$49.1	$55.3	$41.5	$41.5	$41.5	$41.5	$41.5	$41.5	$41.5
Culverts	$9.6	$8.2	$9.5	$7.1	$7.1	$7.1	$7.1	$7.1	$7.1	$7.1
Tunnels	$12.4	$5.2	$12.2	$9.1	$9.1	$9.1	$9.1	$9.1	$9.1	$9.1
Walls	–	$2.4	$3.0	$2.3	$2.3	$2.3	$2.3	$2.3	$2.3	$2.3
Bridge Enterprise	$114.9	$115.0	$132.3	$134.6	$136.9	$139.3	$141.8	$144.5	$147.2	$149.9
Rockfall Mitigation	$9.1	$9.2	$9.0	$5.1	$5.1	$5.1	$5.1	$5.1	$5.1	$5.1
Fleet (Road Equipment)	$20.9	$18.4	$18.7	$14.0	$14.0	$14.0	$14.0	$14.0	$14.0	$14.0
Buildings (Property)	$20.8	$12.9	$15.5	$7.2	$7.2	$7.2	$7.2	$7.2	$7.2	$7.2
ITS Maintenance	$27.6	$21.4	$27.3	$14.8	$14.8	$14.8	$14.8	$14.8	$14.8	$14.8
Asset Management Total	**$755.1**	**$732.1**	**$784.8**	**$745.6**	**$755.9**	**$766.7**	**$777.8**	**$789.4**	**$801.2**	**$813.3**

Source: CDOT

8.5 FINANCIAL SUSTAINABILITY

CDOT's approach to assessing the financial sustainability of the RB AMP is to consider the long-term implications of the anticipated revenues and recommended funding levels on the condition of the transportation system.

For example, Figures 4.1 and 4.2 show the relationship between annual funding levels and future performance. As indicated by the pavement curve in Figure 4.1, the condition of the CDOT's pavements will initially drop (due to the current pavement condition distribution) and then return to current levels between now and 2023 based on the recommended funding. The bridge curve in Figure 4.2 shows that with anticipated funding levels the overall bridge condition will meet the performance goal but will then start to decline at a faster rate after 10 years. CDOT is currently in the process of developing and enhancing performance curves for additional assets and will provide them when this document is updated in two years.

Current revenue projections for the next 10 years, which include the availability of funds from the retirement of bond debt, are based on CDOT's revenue model and are consistent with the Statewide Plan. Based on these projections, funding could be provided for these asset management programs at the levels indicated. However, the actual funding of asset management programs is determined by Transportation Commission directed distribution of these funds within the annual budgets.

9.0 Investment Strategies

This section identifies investment strategies for CDOT's asset management program. The strategies help to define the type, location, and timing of asset management activities that CDOT implements. They are consistent with asset management best practices, will help CDOT achieve the condition targets established in this document, and are part of the overall strategic management of CDOT's assets.

9.1 PAVEMENT

Strategy 1 – Conduct more preventive maintenance on pavements.

Preventive maintenance is 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 crack sealing and filling, concrete joint sealing and filling, ultra-thin asphalt overlays (≤1.5 inches), surface seals (chip seal, fog seal, etc.), micro-surfaces, and patching. The programming of these activities (using surface treatment dollars) into the drivability life (DL) 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 management system, and are typically triggered relatively early in the life of these pavements. This preventive maintenance category adds three to six years of DL to a highway segment, depending upon the traffic loading (in Equivalent Single-Axle Loads (ESAL)). Preventive maintenance is not the only treatment type allowed by the DL system on high- and moderate-volume roadways.

For low-volume roads, there are only two primary treatment types modeled. One 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 the 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, ultra-thin overlays) which is more appropriate for areas of more significant distress and which may be applied in surgical applications to isolated areas only.

Strategy 2 – When selecting surface treatment projects, prioritize Interstates and High- and Medium-Volume roadways over other roadways.

CDOT's pavement condition targets (expressed as a percent of pavements with a high or moderate drivability life) will be established for the Interstates, NHS, and statewide highways. While the percent target is the same for all categories of pavement, CDOT has developed different DL standards based on highway traffic volume. Interstates, high-, and medium-volume roadways have the highest CDOT drivability standards while low-volume roadways have lower acceptable drivability life standards. All acceptable drivability life standards consider the safety and serviceability needed by the 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. Low-volume roadways treatment strategies focus primarily on thin surface treatments. Overall calculated project benefits in the PMS are influenced in direct proportion to traffic volume.

Strategy 3 – Achieve economic efficiencies by coordinating pavement activities with activities on other CDOT 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 Program. 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, and neighboring safety improvement project. While this inter-asset, inter-need, 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 times, 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.

9.2 BRIDGE

Strategy 1 – Conduct preventive maintenance.

The key preservation activities for bridges are based on the observed source of deterioration in bridges that have been replaced for condition-based reasons.

The deterioration observed, in order of decreasing effect on the bridges, was due to: leaking joints, unsealed concrete bridge decks, debris collection on bearing seats below joints, unsealed concrete in roadway splash zones, and unprotected steel. To summarize, the key preservation activities are: repairing, replacing, or eliminating leaking joints; sealing or resealing concrete bridge decks; removing debris on bearing seats; sealing or resealing concrete in splash zones; and painting or otherwise protecting steel in areas where protection is required.

Most preservation activities are triggered based on condition. However, for the purposes of life-cycle cost analysis, the assumed timings are based on historical data: 15 years for joints; 5 to 12 years for resealing concrete decks; 20 years for waterproofing membrane on bridge decks; 2 to 5 years for debris removal; 5 to 12 years for resealing concrete in splash zones; and 20 years for protecting steel.

The preservation action structure only unit costs are:

- Replacing Leaking Joints: $75-$300 per linear foot;
- Sealing Bare Decks: $0.94 per square foot; and
- Installing a Waterproofing Membrane: $15.87 per square foot.

Strategy 2 – Prioritize bridge treatments to preserve structures to prolong bridge service, reduce structure risk of failure due to scour, vertical clearance, and load restrictions.

The primary objectives of the risk-based bridge asset management plan are:

- To preserve the bridges so that they do not have to be replaced for condition-based reasons before capacity needs require the replacement or before the end of their designed service life;
- Reduce risk to CDOT caused by scour-critical bridges;
- Reduce the risk to CDOT caused by bridges with low vertical clearance over state highways; and
- Reduce the impact to commerce mobility caused by load-restricted bridges.

The two identified secondary risks are: poor details that lead to early drops into SD (e.g., fatigue-prone details on steel girders); and fire vulnerability that can lead to loss of a bridge service (e.g.; a timber bridge in the area of a grass fire or a steel bridge exposed to burning fuel). The secondary risks do not yet have identified objectives within the risk-based bridge asset management plan.

Strategy 3 – Consider cost-effectiveness when selecting bridge activities.

Scour critical bridges, bridges with low vertical clearance, load restricted bridges, or FO bridges impact project selection by effecting the priority or eligibility for preservation actions. Scour critical bridges should be ineligible for preservation actions unless there is enough remaining time to SD to make mitigation of the

scour vulnerability cost-effective. Bridges with low vertical clearance should be ineligible for preservation actions unless there is enough remaining time to SD to make mitigation of the low vertical clearance cost-effective. Load restricted bridges should be ineligible for preservation actions unless there is enough remaining time to SD to make strengthening the bridge cost-effective. FO bridges should be ineligible for preservation actions unless there is enough remaining time to SD to make addressing the FO status cost-effective.

9.3 MAINTENANCE

Strategy 1 – Preserve transportation assets.

The whole purpose of maintenance is to maintain assets over time; maintenance is the first line of defense against deteriorating assets.

9.4 BUILDINGS

Strategy 1 – Conduct preventative maintenance.

Controlled and deferred maintenance dollars are distributed to each Region on an annual basis for preventive maintenance activities. The staff who are stationed in these buildings and who see deteriorating conditions on a daily basis are allowed to make decisions on the priority level of required maintenance. Controlled and deferred maintenance budgets are not allowed to be used on F-rated buildings to ensure that these limited dollars are applied to buildings that can in fact be repaired. The goal of preventative maintenance is to keep buildings from reaching the point where they would need to be replaced, or a condition of "F."

Strategy 2 – Address buildings that are rated D or F in 7 to 10 years.

The objective of the Property Management staff is to raise and maintain the entire building inventory to a C or better rating. This goal was developed in order to elevate the current condition of many of the vehicle storage facilities, which provide adequate protection for other CDOT assets (fleet), and to provide a safe work environment for employees. Once a building falls to a D rating, the funds to elevate it are often better spent for replacement. Ideally, the Property Management program would obtain enough funding to move the entire building inventory to a C rating or better over the next 7 to 10 years. This plan includes creating, developing, and constructing new maintenance sites to increase the efficiency of Region Maintenance Patrols. After that period, the budget could be reduced to a level that would allow for the replacement of any buildings that drop below C ratings due to equipment not fitting in the building or other structural deficiencies and apply preventative maintenance treatments to the rest of the inventory to make sure those buildings do not fall below a C Rating.

9.5 ITS EQUIPMENT

Strategy 1 – Follow the manufacturer's recommended maintenance schedule.

Strategy 2 – Apply preventive maintenance.

Besides attempting to follow the manufacturers' recommended maintenance schedule for a device, CDOT tracks devices and uses data to establish preventative maintenance schedules. Collecting and tracking device data enables CDOT personnel to, among other things:

- Ensure that Maintenance Work Orders are used for all device maintenance;
- Schedule regular QA/QC crosschecks that can be used to verify and validate the collected data;
- Identify "bad actor" devices based on device data indicators, i.e., those that have higher than average maintenance costs and/or device or parts obsolescence;
- Identify optimum capital replacement schedules and forecasts; and
- Identify maintenance costs by device, device type, corridor, or region.

Strategy 3 – Enhance ITS program to reflect an asset management approach.

This strategy consists of demonstrating to decision-makers the success of the ITS program and articulating the funding needed to expand device coverage and maintain new devices. It involves moving from a reactive approach to maintaining the ITS infrastructure proactively. To support this endeavor the ITS office is developing a reporting structure and reports to aid in determining a maintenance and device replacement program.

9.6 FLEET

Strategy 1 – Apply preventive maintenance.

CDOT has started capturing preventive maintenance data on the fleet this year. Some existing activities include: oil changes every 8 to 10,000 miles (synthetic oil) or every six months (generally the miles criteria are met first). U.S. DOT requires annual vehicle inspections on the anniversary of the in-service date for every vehicle 26,001 pounds gross vehicle weight (GVW) or greater. These include the vehicles that require a commercial driver's license.

Additional preventive maintenance activities include: daily greasing, manufacturer recommended services, and vehicle pre-trip and post-trip inspections daily on all state vehicles. Air filter costs range from $6 to $80, depending on the vehicle type. Some trucks take two quarts of oil while others

require 10 gallons of oil and the labor and time increases as well with the larger trucks.

Strategy 2 – Update work selection process for replacement to account for fleet functional obsolescence.

CDOT Policy Directive 9.2 is being changed to address asset management. PD 9.2 currently is based on the age and usage of each vehicle. It will now include age, usage, and functional obsolescence. The process includes meeting with the regional equipment managers, developing the basis for the PD, then meeting with the Equipment Management Advisory Committee (EMAC – all deputy superintendents) and finalizing the language. The revised PD 9.2 will then be presented to the maintenance superintendents, traffic engineers and affected branch managers (bridge, drill crew, etc.) before being taken through the formal process of adoption by senior management and the Transportation Commission. Work begins on these changes in November 2013, at which time new data will be available in the SAP reports.

9.7 TUNNELS

Strategy 1 – Replace critical systems on a regular cycle in manned tunnels.

There are several critical systems within the Eisenhower Johnson Memorial Tunnel and the Hanging Lake Tunnel that need replacement on regular cycles. They are costly and the dollars provided to the MLOS Tunnels Maintenance Program Area are not sufficient to address these systems. The failure of some of these systems can result in fatalities to both the traveling public and to CDOT staff. For example, the current Halon fire suppression system in the Eisenhower Johnson Memorial tunnel works by eliminating oxygen from the air to stop the fire from spreading. It cannot be used, however, because it would also result in the deaths of anyone in the tunnel building. Because of the critical nature of this system, CDOT has applied for and received Federal and state funding to replace this system in the next fiscal year. As CDOT goes forward and critical systems are reviewed and upgraded on a regular cycle critical systems will be less likely to require special funding to deal with such safety issues.

9.8 CULVERTS

Strategy 1 – Conduct preventive maintenance.

The key preventative maintenance strategy for steel culverts is to slip line them. Slip lining is usually an epoxy impregnated fiberglass tube that is molded and cured in place. The timing would be triggered based on the culvert condition just prior to perforation of the invert. Slip lining can also be an effective treatment so long as the invert has not begun to project up into the culvert

opening. Depending on the slip lining method chosen it can provide structural capacity and be considered a replacement.

The same slip lining technique can also be used for concrete culverts as a preventative maintenance strategy. The trigger for this treatment would be when the invert concrete has been abraded or spalled off enough to expose the reinforcing steel but before the reinforcing steel has significant section loss due to corrosion. The average unit cost used for slip lining is currently $1,700 per linear foot or $425 per square foot.

Strategy 2 – Transition from a worst first program to one based on asset management.

The current risk-based asset management plan for minor structures is to address the essential repair finding backlog by replacement, major rehabilitation, or repair to avoid loss of roadway service due to a minor structure failure. This "worst-first" approach was developed once the magnitude of the backlog of essential repair findings was identified. The minor structures program is expected to begin to include preservation strategies such as slip lining once the backlog of critical culverts is reduced to a management level, defined as when the number of essential repair findings is at or below the annual rate of new essential repair findings.

9.9 ROCKFALL MITIGATION SITES

Strategy 1 – Conduct preventive maintenance.

It is understood that maintenance for many rockfall mitigation devices is performed reactively. However, mitigation such as scaling at rockfall sites can be performed on regular intervals to reduce the amount of rockfall at specific locations. The timing interval for programmatic scaling efforts is dependent on the geology of the slope but can be estimated to be between three to five years on average. Rock scaling is paid for on an hourly basis.

Strategy 2 – Assess preventive maintenance cost-effectiveness to identify alternative mitigation methods.

Mitigation devices are evaluated on the need to repair the device or update the mitigation method. As an example, if a concrete barrier is used to enhance a rockfall catchment ditch is requiring replacement more than once per year, an updated mitigation scheme offering a similar or higher level of protection will be presented. In the case of the concrete barrier, installation of rockfall netting could be proposed. The cost of these alternate mitigation methods is site-specific.

Strategy 3 – Enhance rockfall program to reflect an asset management approach.

- Provide a site selection guideline that mitigates rockfall hazards identified in the Colorado Rockfall Hazard Rating System.
- Reduce the risk to the traveling public for safety and mobility.
- Allow for the allocation of resources to unexpected or unplanned rockfall needs.
- Manage the existing rockfall mitigation assets constructed by previous projects or installed by CDOT Maintenance staff.

Refer to Section 7.0 for a description of the Rockfall Risk Management Plan and how it fits into the overall risk management effort at CDOT.

Part II

Improving CDOT's Asset Management Process

10.0 Asset Management Gap Assessment

The first step in improving CDOT asset management process was to conduct a gap assessment. This section describes the gap assessment process, which included previous surveys and interviews with staff, as well as comments from NHI instructors at CDOT TAM workshops. The process provided CDOT a starting point for identifying and prioritizing opportunities for improvement. An implementation plan for addressing the priority gaps is provided in Section 11.0.

10.1 GAP ASSESSMENT PROCESS

The gap assessment was meant to set the stage for specific asset management enhancements, and help foster development of an agencywide vision of asset management. Therefore, the assessment approach involved "digging wide AND deep" in order to uncover candidate improvements for consideration.

The process used in the gap assessment considered the results from the AASHTO asset management self-assessment exercise, as well as several other sources of potential gap information. After assembling and reviewing these sources of information in detail, the next step was to identify potential gaps and then package these candidate gaps into a meaningful framework. This framework served as not only a repository of candidate gaps, but also as a method and tool for prioritizing the gaps so that implementation plans can be formulated.

The following paragraphs describe each of the columns in the table, and the purpose of the columns.

Categories of Gaps

CDOT considered gaps into the following areas:

1. Policy Guidance;
2. Planning and Programming;
3. Program Delivery;
4. Information and Analysis; and
5. Organizational.

The "Organizational" category was added to the list from the AASHTO self-assessment exercise because there was no obvious place to put the "people" aspects of potential gaps. "People, Processes, and Technology," in management circles, are the three-legged stool to consider regarding effective change in an organization. This additional category was valuable in capturing all the needs of CDOT.

Sources of Potential Gaps and Supporting Rationale

Significant rigor was brought to bear in the assessment of candidate improvement areas for CDOT. This rigor began with a review of pertinent documents and presentations at CDOT, including:

- Performance Reporting and Asset Management Briefing (December 2012);
- Asset Management and PD 14 Briefing (January 2013);
- Asset Management and MAP-21 Briefing (January 2013);
- Memo to the Transportation Commission (February 2013);
- CDOT Asset Management Updates (February 2013); and
- RAMP Policy Briefing (February 2012).

These documents reflected the current policies and directions that are being pursued at CDOT and served as a solid starting point for further exploration and definition of candidate improvement areas.

Beyond the literature review, a very important aspect of the gap assessment is that it is based on myriad, substantive additional "Sources" of information. These include:

- Risk Evaluation Workshop (February 2013);
- RB AMP Kickoff Meeting (March 2013);
- National Highway Institute (NHI) Training Sessions (April and July 2013);
- AASHTO Self-assessment (April 2013);
- NHI Instructor Notes from the April 2013 NHI Training Sessions; and
- Interview sessions with CDOT personnel.

The first two meetings included group discussions where several ideas for improvement were identified. The Risk Evaluation Workshop was held to consider various types of risk in TAM. As a result, potential gaps were brought forward and discussed relative to TAM in general.

Similarly, during the RB AMP Kickoff Meeting, a large group discussion took place, and the context of the discussion was the entire arena of asset management. Therefore, the topics were very wide-ranging, but individual gaps were discussed in good detail and captured. In addition to the overall group

session, there were breakout sessions for several of the program areas, which provided even more detail to the gaps that were being suggested.

During the NHI Asset Management Training in April 2013, there was ample opportunity for gaps to be brought up and discussed. The training stimulated many relevant ideas. In addition, the training included breakout sessions on the top five gap areas that were emerging from the discussions. These breakout groups fleshed out these key areas in very good detail for further definition and evaluation.

In conjunction with the NHI training, the group of attendees individually responded to the AASHTO self-assessment exercise prior to the training. In this way, the results could be presented and discussed as part of the training sessions. Not only were these discussions valuable, but the results were also factored into the overall gap assessment.

Finally, regarding the NHI Training sessions, the instructors noted their own thoughts on what areas of improvement for CDOT might be the most beneficial. These notes are valuable not only because of the experience of the instructors in identifying improvement areas, but because they interacted with CDOT personnel over a period of two days regarding asset management implementation, and thus had a good understanding of what challenges the agency might be facing.

A major effort during this overall process was conducting interviews with CDOT personnel from several of the program areas. The interviews were guided with the use of a diagnostic tailored for CDOT. In other words, several relevant and targeted questions were provided to the interviewees in order to stimulate discussion and reflective consideration of CDOT's capabilities in many areas. In addition, the interviews were a good forum for creative brainstorming of a variety of ideas for potential improvements.

Notes, results, and outcomes from all these sources of information were assembled and reviewed thoroughly in searching for predominant themes and opportunities for improvement. Based on these sources of ideas and priorities, the prevalent and recurring candidates of potential gaps are noted in the Gap Assessment Table.

Importance, Urgency, and Ease to Implement

In order to prioritize the gaps, CDOT's consultants first evaluated the identified gaps in terms of their overall importance to the asset management mission using a scale from 1 to 5, with 5 being greatest importance. Next, the "Urgency" of filling the gap was rated. For example, a gap can be important, but not urgent; hence it would be of lesser priority than a gap that is important AND urgent. The scale is from 1 to 5, with 5 being the most urgent. Finally, the "Ease" with which a gap could be addressed was considered. The scale is from 1 to 5, with 5 being the easiest to implement. Rating the ease of implementation will help to

prioritize the gaps, schedule them and assist in determining necessary resources for implementation.

The consideration of Importance, Urgency and Ease is similar to assessing the benefit/cost of an initiative, where the importance and the urgency of filling a gap can be a proxy for the benefit, and the ease of the implementation efforts to fill the gap is the inverse of the cost of filling the gap. Hence, if these three ratings (i.e., Importance, Urgency, and Ease) are multiplied together, the result is a score that can serve as an indicator of overall priority of addressing each gap.

CDOT conducted a workshop with CDOT staff in order to review and vet the results of the gap analysis and to prioritize the gaps. The prioritized list becomes the basis for the Implementation Plan.

10.2 RESULTS AND RECOMMENDATIONS

Table 10.1 lists the prioritized gaps that resulted from the process described above.

Table 10.1 Gaps Recommended for Implementation

No.	Title	Category	Gap	Desired State	High-Level Steps Being Taken to Achieve Desired State
1	Develop and Document the Budget Distribution, Project Selection and Project Tracking Process	Planning and Programming	The complete process from needs assessment to how funds are distributed is not documented. Part of this process occurs during the PD 14 process, part occurs during the long-range planning process, part occurs during the annual budgeting process, part occurs when funds are distributed to the regions, and part occurs when funds are assigned to specific projects. Documentation on some of these steps exists in various documents, but there is no comprehensive description of how funds are distributed.	The entire process of how asset management funding is distributed is documented. This includes documentation by each asset manager detailing the process for selecting projects ensuring tradeoffs and corridor priorities are factored in to ensure optimal value.	All asset managers are in the process of improving their systems. CDOT also began developing swim lanes in October 2013 to better illustrate how funds are distributed.
2	Integrate Risk Analysis into Planning and Programming Processes	Information and Analysis	Need to better understand, assess, and communicate potential risks for the purposes of transportation planning, asset management, project selection and budget setting; and how does asset risk relate to CDOT Operations?	A mature knowledge set regarding risk events, their probabilities, and their consequences, as well as candidate mitigation strategies, costs, benefits. Understand how to quantify risk during bridge construction for example.	The Rockfall program is formulating a Mitigation Plan, due June 30, 2013, as well as conducting a Feasibility Study.
3	Develop Strategies to Manage Project and Program Delivery Risks	Planning and Programming	There is a gap between understanding the asset management philosophy and implementing it, as far as distributing funds to assets in a way that makes sense to the program. Managing the uncertainty as well. Changing the Surface Treatment project list midstream may have a significant cost to CDOT.	Communicate the cost of changing business philosophies/ideologies to asset management. The impacts of not delivering projects as planned are quantified.	Somehow need to quantify the financial impacts of making these major changes to the organization. Also need to understand impacts on project deliveries such as revenue uncertainties.

No.	Title	Category	Gap	Desired State	High-Level Steps Being Taken to Achieve Desired State
4	Establish a Risk Framework to Evaluate Alternative Strategies	Planning and Programming	An overall framework to consider mitigation strategies for various risk events/sites is needed, as well as for comparing and trading off investments across various risk opportunities. Need to merge "risk-based" management with "performance-based" management of assets.	Risk opportunities – a framework to include the opportunities and threats related to uncertain events, and tradeoff the ROI of candidate risk mitigation strategies.	CDOT has engaged a consulting firm to provide tools for characterizing the consequences of various risks, and these tools will be valuable in supporting the larger risk framework.
5	Analyze Budget Tradeoffs Across Programs	Planning and Programming	The type and impact of maintenance work on pavement and bridges and their impact on extending the life of these assets is not clearly understood. There is a need to better understand the investment of capital and the subsequent impact to maintenance.	Capital versus maintenance expenditure tradeoffs are explicitly considered in the preservation of assets like pavements and bridge.	The new Bridge Maintenance Report is assisting bridge analysis, while the Roadway Surface-Surface Treatment project is working to better understand the relationship on the pavement side.
6	Improve Project Scoping and Optimization	Policy Guidance	Disconnect between Statewide Plan and Asset Management. Corridor planning does not recognize that maintenance needs are increasing and funding should be based on the asset need, not on a formula. Continuity between corridor plans and the targets used in asset management as well as ties to the Maintenance program operations are missing.	Corridors defined to support asset management, spanning regions and terrain types; and Maintenance is tied to long-range plans.	New statewide long-range plan is being written and is intended to address corridor ties to asset management considerations.
7	Incorporate Life-Cycle Analysis into Decision-Making	Information and Analysis	The Bridge Program does not currently include preventive maintenance in its life-cycle analysis of bridges, or in the types of projects that are performed.	Ability of the Bridge Program to express performance and life as a function of investment level, including preventive maintenance expenditures.	Staff Bridge is working to incorporate preventive maintenance into its analysis; starting with those elements with the highest ROI. These first two considerations are whether or not a bridge has joints, and whether or not the bridge deck is sealed.

No.	Title	Category	Gap	Desired State	High-Level Steps Being Taken to Achieve Desired State
8	Clarify the Role of Target-Setting	Policy Guidance	Staff is not clear on whether targets set in PD 14 and the RB AMP should be desired targets or those targets that can be achieved given very limited funding. Meaningful targets need to be adjusted periodically based on changes in projected revenues, actual results versus planned, etc., and therefore need to be set as a function of projected program revenues, projected performance, and tradeoffs between programs. Some programs (bridge) have hard targets; some have aspirational goals (MLOS).	Need specific, measurable, agreed-upon, realistic, and time-bound (SMART) objectives for all assets, consistently communicated in all venues/reports, with time horizons, which are revisited and adjusted.	PD 14 is being rewritten, and there is a need for better communication on this aspect of the PD.
9	Implement a Strategic Management Framework to Reflect on Progress	Policy Guidance	Need a methodology to review if the work recommended by asset management systems is in fact the work that has been done.	Ability to "close the loop" on strategically managing TAM, with methods such as "Plan, Do, Check, Act," or equivalent.	Consultant on Project Portfolio Management will help with engineering projects and reviewing what was done compared to what was planned.
10	Communicate the Benefits of TAM	Policy Guidance	Asset management is a new way of doing business and requires changes in CDOT's culture and processes. This new approach is being developed and needs to be communicated effectively. Need change management strategy. Need to communicate externally as well. Need to factor in increased maintenance to low-volume roads.	Regional rollout and change strategy is in place, including organizational alignment for TAM.	Roadshow by senior management will focus on asset management; new policy and procedural directive are being created for asset management. TAM Intranet site provides information. External website to be created; asset management discussion with external stakeholders has started with Statewide Transportation Advisory Committee (STAC).

The highest priorities for further developing asset management capabilities at CDOT, based on the process described above include Items 1-10.

1. **Develop and Document the Budget Distribution, Project Selection and Project Tracking Process –** There is a need to define and document the new statewide, asset management-driven budget setting and distribution process. This was a major gap at the beginning of 2013. This process includes components of the PD 14 update process, the annual budgeting process as it relates to asset management, distributing funds to the regions, and allocating funds to specific projects. Asset management efforts underway at CDOT are already significantly addressing this gap. As CDOT continues to make improvements to the process, the documentation will also be updated.
2. **Integrate Risk Analysis into Planning and Programming Processes –** There is a need to better understand, assess and communicate potential risks for the purposes of planning, asset management, and budget setting. In the fall of 2013, an asset management risk register for CDOT was established for the first time. The register addresses agency, program and project-level risks.
3. **Develop Strategies to Manage Project Delivery Risks –** There is a need to improve the ability to manage the risks related to project delivery, including uncertain revenue, political priorities, and volatility of construction costs.
4. **Establish a Risk Framework to Evaluate Alternative Strategies –** In the summer of 2013, an overall framework to consider mitigation strategies for various risk events/sites was needed. This framework was needed for quantifying the benefits and costs of candidate mitigation strategies as well as for comparing and trading off investments across various risk opportunities. Because of a concerted action plan, a framework has been established. Additional work is needed in order to include more risk opportunities into the investment analysis, as well as compare and tradeoff risk opportunities with performance-based investments. CDOT will continue to document progress as it develops.
5. **Analyze Budget Tradeoffs Across Programs –** In general, cross-asset optimization is a capability that will be improved at CDOT. Specifically, there is a need to better understand the implications of trading off investment dollars in one program versus another program, and comparing the associated performance gains and losses. Understanding these compromises will allow better overall investment decisions in the future.
6. **Improve Project Scoping and Optimization –** There is a need for improved project scoping in order to assure that there is a direct linkage between intended investments and actual spending. For example, for highway rehabilitation projects, it is important to understand the cost components (surfacing, structural work, shoulder widening, signs, etc., and their impact on drivability.) in order to compare the actual expenditures to the original objectives of the project. This discipline will help clarify the linkages between TAM objectives and project development. Similarly, there is a lack

of continuity between CDOT plans and asset management targets for Maintenance program operations. Specifically, planning does not recognize that maintenance requirements are increasing and funding should also increase to reflect the goals of the agency. Hence, connecting the intended TAM objectives with actual investments need to be improved. The GIS capabilities at CDOT will be of great value in enabling this process improvement.

7. **Incorporate Life-Cycle Analysis into Decision-Making –** The type and impact of maintenance work on pavement and bridges and their impact on extending the life of these assets are not clearly understood. The Bridge Program, for example, does not currently include preventive maintenance in its life-cycle analysis of bridges (although this effort is underway). There is also a need to better understand the investment of capital and the subsequent impact to maintenance. To meet this overall need at CDOT, a more consistent understanding and usage of life-cycle cost analysis will support better investment decisions across asset classes. Effort to coordinate MLOS pavement maintenance activity and pavement asset management now underway.
8. **Clarify the Role of Target-Setting –** Targets set in PD 14 and the RB AMP can be desired targets or targets that can be achieved given very limited funding. Meaningful targets need to be adjusted periodically based on changes in projected revenues, actual results versus planned, projected return-on-investment across programs, etc., and therefore need to be set as a function of projected program revenues, projected performance and tradeoffs between programs.
9. **Implement a Strategic Management Framework to Reflect on Progress –** CDOT needs a methodology to review if the work recommended by asset management systems and selected by staff for projects is in fact the work that has been done. This capability should include an ability to "close the loop" on strategically managing TAM, with methods such as "Plan, Do, Check, Act," or equivalent. This capability will enable continuous improvement, maximize savings and value creation, and sustainability of the TAM effort.
10. **Communicate the Benefits of TAM –** Asset management has been used for years at CDOT supporting bridge and pavement project selection decisions. The Maintenance Levels of Service (MLOS) system has incorporated a statewide approach for LOS for years as well. Now for the first time CDOT is using its asset management models to determine statewide priorities, instead of determining the priorities in each region and allocating funding based on an equity formula. This a new way of doing business and requires changes in CDOT's culture and processes. This new approach is being developed and needs to be communicated effectively, both internally and externally. These needs are being addressed internally through CDOT's Change Agent Network (CAN) and externally through Executive Director Hunt's Listening Tours across the State.

11.0 Asset Management Implementation Plan

This section presents an implementation plan for addressing the priority gaps defined in Section 10.0.

11.1 Process for Developing the Implementation Plan

Following the Gap Assessment, the objective was to develop an asset management implementation Plan that addresses CDOT's priority gaps. The approach to this task included the following elements:

- Consider gap priorities in scheduling the order in which gaps are addressed. For example, schedule the high-priority gaps early on if possible;
- Consider the dependencies between gaps to be resolved. For instance, it may not make sense to consider some gaps until others are resolved (e.g., a data collection effort may need to precede the enhancement of an asset management system for an asset class);
- Identify a Project Lead for each Gap;
- Identify resources required; and
- Define the schedule to complete.

11.2 Expanding the RB AMP to the Entire NHS

A cross-cutting theme throughout the implementation plan is a need to address all NHS pavements and bridges included in the post-May 2013 NHS in the next version of the RB AMP. As discussed in Section 3.0, this document focuses on assets owned and maintained by CDOT today. While the State system goes well beyond the NHS, it does not cover the entire NHS. CDOT owns 90 percent of the NHS in Colorado. Furthermore, MAP-21 requires that asset management plans address all NHS pavement and bridges. As CDOT moves forward with each of the items below, it will address how to pull the off-system parts of the NHS into subsequent versions of the RB AMP.

11.3 Implementation Plan Dependencies

Of major importance in the development of the Implementation Plan are the interdependencies between gaps, such as the prerequisites that might be

necessary for work to begin. For example, program budget tradeoff analysis capabilities are required before a budget process can be fully mature. Such dependencies have been considered in the development of this Implementation Plan.

One such dependency affects CDOT's overall strategic framework for asset management. In order to have a fully integrated management framework for asset management, several of the current decision-making and planning processes must be linked to asset management. A good example is the Statewide Transportation Plan (SWP). Others include performance measurement of personnel, branches, etc., and how these parts of the organization tie into the success of asset management. The strategic management framework presents a "Catch-22" of sorts, which means that this framework must exist in order to tie the various management and decision-making processes together, but it will not be fully mature until all parts are operational TOGETHER. Therefore full implementation of the "Plan, Do, Check, and Act" framework described in Section 6.0 is important so that all relevant processes are effectively managed.

Other dependencies identified for developing asset management capabilities at CDOT include the following:

1. **Develop and Document Budget Distribution, Project Selection and Project Tracking Process –** These processes will be improved for the FY 2017 cycle. For FY 2017 the Tradeoff Analysis capability will be included. The budget process will be integrated into the overall Strategic Management framework at CDOT as discussed in Section 6.0.
2. **Integrate Risk Analysis into Planning and Programming Processes –** Each asset program will improve their capabilities in characterizing, packaging and evaluating risk mitigation opportunities. This capability will develop over time, and feed the risk framework, which eventually feeds the Strategic Management Framework.
3. **Develop Strategies to Manage Project and Program Delivery Risks –** Developing the capability to analyze and mitigate project delivery risks at CDOT will take several months to accomplish. This capability will eventually feed the CDOT risk framework, and be incorporated into the "Do" phase of the Strategic Management Framework.
4. **Establish Risk Framework –** As defined in Section 8.0, this framework will provide for the consideration of all risk-based opportunities at CDOT in the Strategic Management Framework.
5. **Budget Tradeoffs –** The ability to perform cross-asset tradeoff investment opportunities and within programs will be added to the asset Budget Process for FY 2017 funding distribution.
6. **Improve Project Scoping and Optimization –** It is important to understand where money has been spent in the past and on what objectives. For example, for a major rehabilitation project, what were the cost components

(surfacing, structural work, shoulder widening, signs, etc.). Then these actual expenditures can be compared against the original objectives of the project. This effort will lay the groundwork for Gap No. 9 and specifically the practice of "plan versus actual analysis," and will help improve the linkages between TAM objectives and project development.

7. **Incorporate Life-Cycle Analysis –** This capability, including the Bridge program's efforts at defining the benefits of preventive maintenance, will be essential across all programs in order to perform budget tradeoff analysis. Therefore the development of this capability will feed the investment tradeoff capability for usage in developing the FY 2017 program budgets.
8. **Clarify the Role of Target Setting –** This capability will be utilized in formulating the targets, and hence the program budgets for the FY 2017 budget. This capability then feeds into the development of the asset Budget Process.
9. **Implement Strategic Management Framework –** A cornerstone of the TAM capabilities at CDOT, this capability serves as the framework of relevant processes that will be utilized. See Section 6.0 for a full description. In short, the budget-setting processes and other planning and decision-making processes all feed into the Strategic Management Framework as does the risk framework, including the project delivery risk mitigation capabilities.
10. **Communicate Benefits of TAM –** TAM activities will be communicated early in calendar 2014, and will need to be continued thereafter in order to take note of the successes and lessons learned in performing concerted.

11.4 IMPLEMENTATION PLAN DETAILS

Following are the first steps in the implementation plan to address the gaps identified for asset management at CDOT, along with additional details. Also see Table 11.2.

No. 1 – Budget Distribution, Project Selection, and Project Tracking Process

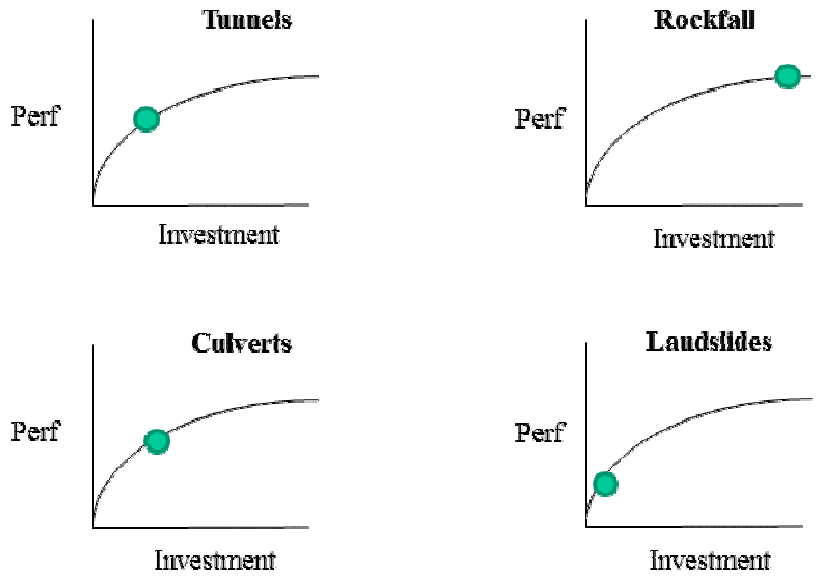
The highest priority at this time for staff to have a clear understanding of the process used by each asset from needs assessment to budget distribution. The first task for the RB AMP Implementation will be for each asset manager to document in one comprehensive standalone document the process for how asset condition is assessed, how projects/equipment are selected, a summary of their funds, and the projects/equipment in their three- to five-year plan. The documentation must factor in a risk analysis and use financial measures to demonstrate that the projects/equipment selected provide the optimal value for CDOT's funds. It should also list the current project list, and describe how those projects will ensure that performance targets are met. This is a living document so it will be updated and therefore will provide asset managers with an

opportunity to reassess their asset management strategies, which are discussed in Section 9.0.

No. 2 – Risk Analysis

The risk register presented in Section 7.0 provides a prioritized list of risks. The next step for CDOT is to determine mitigation strategies, and then quantify their costs and benefits. This type of benefit/cost analysis will enable CDOT to develop risk investment curves such as the example presented in Figure 11.1. These curves can be used by CDOT to facilitate the comparisons and select the best mitigation investments. This approach will also enable the comparison of risk-based investments with performance-based investment. By comparing curves like that illustrated in Figure 11.1, CDOT can conduct a formal tradeoff analysis. Tradeoff analysis is described in more detail in a following section.

Figure 11.1 Sample Risk Investment Curves



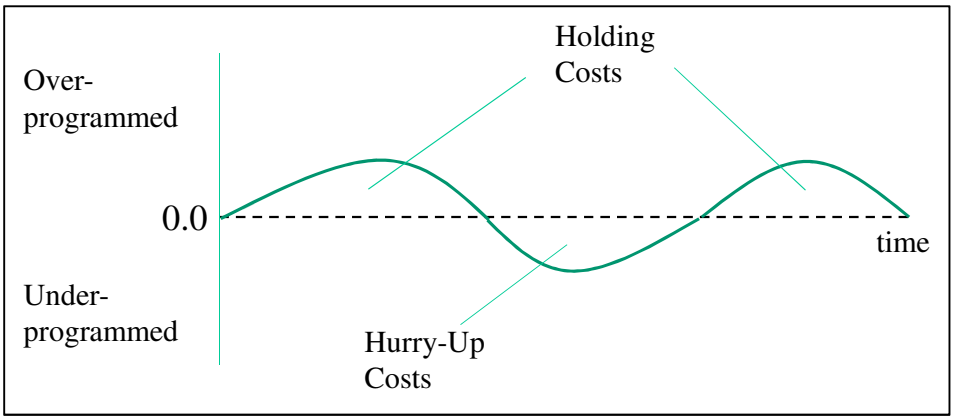
No. 3 – Project Delivery Risks

Research conducted at WYDOT has shown that mismatches between available funding and the number of projects that are "ready to go" can result in significant financial costs to a DOT. These costs have been defined as "Holding Costs" if there are too many projects on hand and "Hurry Up Costs" if there are too few projects ready to go. The goal of previous research has been to identify significant process improvements to ensure projects are delivered on time and as

intended, thus maximizing the miles paved and minimizing financial risks to the organization.[10]

As shown in Figure 11.2, there are costs in programming either too many projects or too few projects. Having too many projects ready to go is referred to as being "over-programmed." This means there is not enough money to fund projects that are ready to be delivered, resulting in significant "holding costs" when these projects sit on the shelf. When there are not enough projects ready to go, this is referred to as being "under-programmed." This means there is an excess of available funds relative to the projects that are ready to go. Similar to being over-programmed, there are costs to being under-programmed. For instance, accelerating project design in order to "use or lose" funding that is available is just one of the "hurry-up costs." CDOT is forecasting steady funding over the next 10 years for asset management using anticipated revenues and cash flow management, which will reduce these concerns.

Figure 11.2 Over-Programming and Under-Programming of Projects



When there are revenue shortfalls year after year, research has shown that the organization can see significant cost impacts due to project delays. Holding or delaying projects and not being able to deliver them as originally intended often results in project splits, cost escalation during delays, project redesign, and down-scoping of projects (resulting in significant cost increases and lower performance than originally anticipated). Likewise, when there is an unexpected influx of money (i.e., stimulus funds or extra highway funds), there are costs of accelerating projects if there are not enough projects ready to go.

Overall, a balance between Holding Costs and Hurry-up Costs must be maintained in order to deliver the maximum amount of projects as intended over time.

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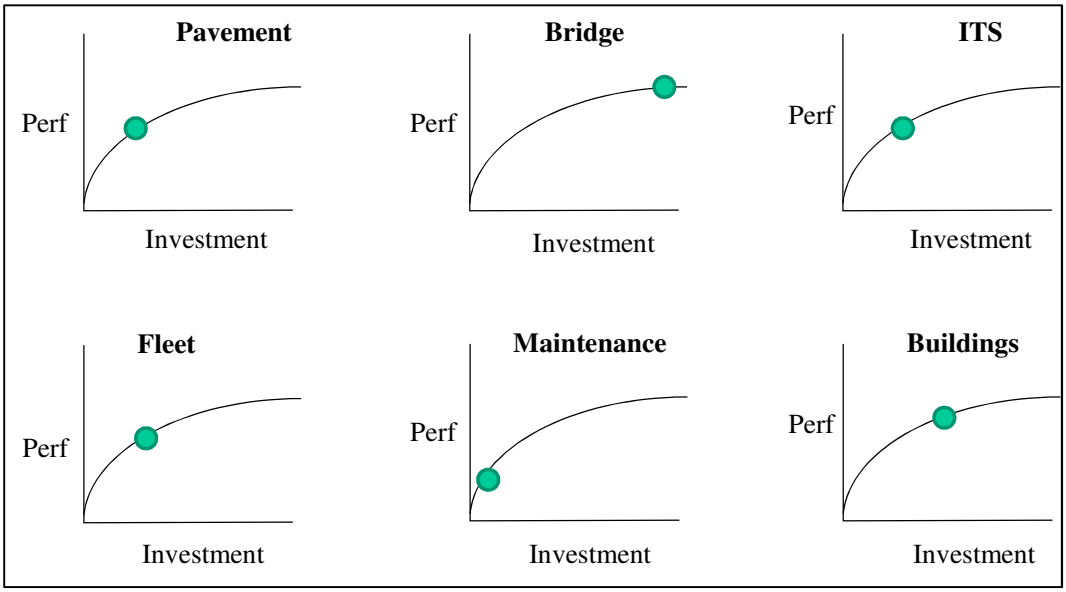
[10] Redd, L.R. and Redd, K.A., *Managing Risks in the Project Pipeline*, Report Number FHWA-WY-13/06F, September 2013, Wyoming Department of Transportation (Final Report).

No. 4 – Risk Framework

CDOT places a strong emphasis on the ability to compare investments across programs. Figure 11.3 illustrates how a variety of investment strategies can be considered across several of the major programs. These small graphs may depict, for example, the performance of each program on a 10-year time horizon versus how much average annual investment might be applied to each program. This is a traditional manner in which to view investment versus performance for familiar asset classes. One possible approach for risk-based investments is to analyze them similarly.

Figure 11.3 Sample Performance Curves (Not CDOT-Specific)



Note: These curves are examples only and do not reflect CDOT data.

With this as a framework for viewing investment choices across programs, a key objective was thus identified. This objective was to be able to merge the consideration of risk-based opportunities with performance-based opportunities in the overall investment analysis of TAM. The following paragraphs describe the approach to developing these capabilities at CDOT for rockfall mitigation:

1. Identify risk event types, categories, classes, etc.;
2. Understand the probabilities and consequences of these risk event types;
3. Identify mitigation methods for these risks;
4. Determine how to "package" risk management efforts;
5. Calculate the benefits and costs of mitigation candidates for each high-risk event;
6. Create "performance curves" for risk mitigation candidates to help prioritize these efforts/investments;

7. Portray the investment versus risk mitigation performance for a 10-year horizon; and
8. Include risk opportunities in the overall asset management investment tradeoff analysis as part of the program distribution process.

Managing System Risks

There also is a need to take a systemic look at risks across Colorado, and apply more holistic approaches to managing these risks. These types of risks are more extensive than events that occur in isolated locations, and could involve large areas of the State and varied terrain.

In general, system risks can pose significant hazards to CDOT and they may not be asset or site-specific. The following are a few characteristics of system risks:

- Example – Flood of September 2013 in Northern Colorado:
  - Involved burn areas, heavy rains, debris flow, multiple asset types, etc.; and
  - Was a rare event, but with devastating consequences over a large geographic area.
- System risks can involve large geographic areas, and complex topography.
- Assets other than CDOT's may be involved, including utilities, forests, dams, watersheds, homes, etc.

Analyzing system risks will involve an extended capability beyond traditional means of categorizing and managing risks. Due to the complex nature of myriad assets that are potentially affected, and the cause-and-effect mechanisms that might be involved, special analysis may be needed. An effective approach used in these types of situations involves scenario analysis and has already been utilized by organizations involved in risk management. It is similar to approaches used by the Red Cross, FEMA, USGS, and NCAR (National Center for Atmospheric Research).

Considering system risks will provide CDOT with additional rationale for making important decisions. The department will be able to consider project selection decisions and risk response options beyond the bounds of traditional asset management methods. These decisions will include:

- Consideration of reconstruction options in the mountain terrain and canyons of Colorado versus the probability or severity of events. In other words, by spending additional funds on more robust construction methods, the road may withstand a 100-year flood, but not a 500-year flood.
- Analyze the tradeoff of mitigation methods versus risk transfer or risk response options. For existing construction, the consideration of system risks may enable more insight into identifying and selecting mitigation or other risk management techniques.

A key requirement of managing system risks is to be able to better analyze and understand options for packaging mitigation methods and investments. Since more than one asset type may be involved, and more than a specific site may be involved, the following types of mitigation types will need to be considered:

- Site-specific mitigation options;
- Corridor-based mitigation options; and
- Regional or statewide projects/programs.

These types of potential mitigation strategies are further described in Table 11.1.

Table 11.1 Managing System Risks

Strategy Prong	Targeted Risks	Approach
Site-specific activities	Rare, but catastrophic events (a.k.a. "black swans")	Efforts to preclude, mitigate, or respond to these events
Corridor-based investments	Hazards to corridor mobility	Corridor-centric strategies, projects, or activities
Regional or statewide efforts	Respond to higher frequency, lower impact events, or preclude or project the onset of higher impact events	Dedicated, broad-based projects, and/or ongoing maintenance

CDOT's overall goal of managing system risks is to be able to make investment decisions regarding risks that involve more than one type of asset, and more than one specific event site. These types of decisions are beyond the capabilities of current asset management analysis capabilities, and will provide great opportunity to the department in reducing costs and providing more value to the traveling public.

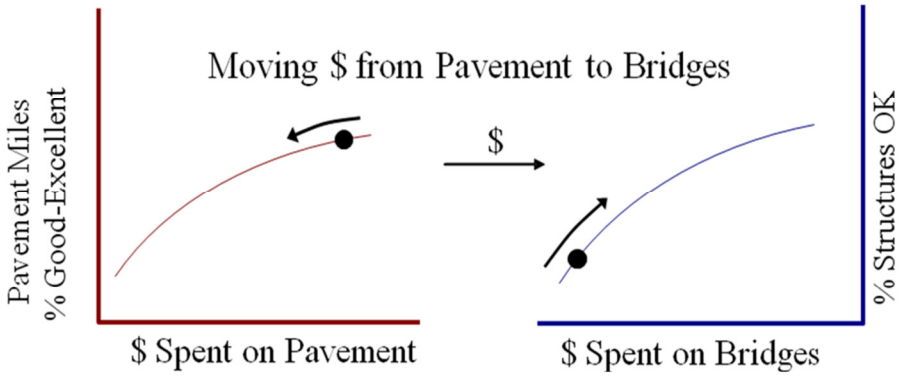
No. 5 – Budget Tradeoffs

CDOT's management systems are capable of producing performance curves for each program. The graphs shown in Figure 11.3 are examples depicting that when investment increases for a given asset class, additional performance from that investment is generally the result.

These sets of data are instrumental in performing tradeoff analysis. As an example, the two graphs in Figure 11.4 show how moving investment dollars from one program to another, e.g., from Pavement (PMS) to Bridge (BMS), would have the effect of increasing the health of one asset class (network-wide) versus decreasing the health of the other. As illustrated in Figure 11.4, when a decision-maker considers moving money from Pavement to Bridge, for example, the Pavement performance will drop and the Bridge performance will rise. The question is, how far to go in looking for the best levels of expenditures across these programs.

Value add or cost savings from tradeoff analysis is accomplished by finding where overall value is maximized, i.e., "finding the most favorable compromises." This is the investment mix that maximizes the overall return on investment for both asset classes combined. The analysis should initially seek to find the point where money taken from one program will not degrade the overall health of that program significantly, but when this money is provided to another program the increase in the second program's health is significant. In this situation, an increase in "value-add" has occurred. Alternatively, if both programs can easily meet their required targets for program health, then perhaps a cost reduction can be captured. If neither program can meet their targets, a case can be made for additional funding. The ability to examine these types of scenarios is a very important feature of tradeoff analysis.

Figure 11.4 Sample Investment Tradeoff Analysis between Pavement and Bridges



No. 6 – Project Optimization

There is a need for improved project scoping in order to assure that there is a direct linkage between intended investments and actual spending. As part of this, it is important to understand where money has been spent in the past, and on what objectives. Then the agency can begin to understand how well plans are currently being carried out. Shortcomings in the linkages between intended spending, actual spending, and targets achieved are then improved over time.

As an example, research at the Wyoming Department of Transportation (WYDOT) found that 45 percent of the cost of major pavement rehabilitation projects was unrelated to the surfacing work "between the white lines." Therefore, the other costs and the objectives of these investments received more

scrutiny following this research. WYDOT continues to track actual expenditures on projects, comparing them to the TAM goals of the agency.[11]

The benefits resulting from improved project scoping may include:

- Ties between corridor plans and TAM targets are clarified;
- "Plan versus Actual" analysis regarding intended spending, actual spending, and targets achieved thus resulting in better target-setting and usage of scarce funding;
- Finding the synergies and compromises between the various programs and their objectives for a given stretch of road can result in great savings and value-add; and
- Project sizing to minimize the impacts of fixed overhead costs, or to avoid the expensive choice of splitting projects if funds are not available.

Usage of GIS and mapping capabilities can assist in project optimization tremendously. Preparation of roadway information and features for viewing and analysis can be extremely valuable in developing and scoping projects. Below are some examples of high-value geospatial data:

- Viewing crash data along with roadway features to facilitate safety analysis;
- Pavement conditions, intended years of construction, etc., alongside similar data for bridges in order to assist in overall project scoping and strategy development;
- Maintenance cost information together with anticipated Pavement or corridor improvement projects; and
- Risks from various categories of hazards can be portrayed along with probabilities and potential consequences.

No. 7 – Incorporate Life-Cycle Analysis into Decision-Making

While many assets at CDOT incorporate life-cycle information into their analyses, there are areas for improvement. For example, the bridge program is currently working on how to incorporate and quantify the benefit of preventive maintenance activities in extending the service life of bridges. The pavement and pavement maintenance groups are currently evaluating how surface treatment projects and maintenance activities can be managed more cohesively for each corridor. Once this is better understood, the same types of activities should be discussed between bridge and bridge maintenance staff. These enhancements to the current analysis will improve assets across all corridors in Colorado.

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[11] Redd, L.R. and McCarthy, J.M., *Effective Implementation of Investment Tradeoff Analysis*, presentation to the Transportation Asset Management Conference, Portland, Oregon, October 2009.

No. 8 – Clarify the Role of Target-Setting

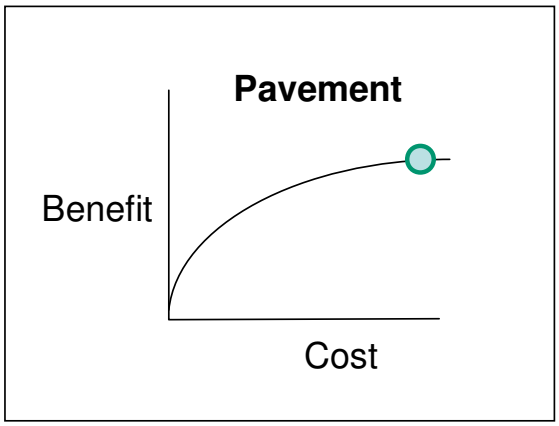
Typically, disparate asset classes have performance measures that are expressed in different units. Unless decision-makers create an overarching policy that establishes what "value" means across asset classes and programs, in common units, then further analysis regarding investment distributions will be necessary. Therefore, it is essential to have the tools and processes that enable decision-makers to make investment tradeoffs, set targets across programs with confidence, and then communicate the results.

The primary goal is to distribute the total budget across programs in order to create the most value across programs, and across the network. In other words, the goal is to drive the highest performance across programs with a given budget. With constrained funding, this consists of adjusting the investment level in each program, without exceeding the total budget amount, in an effort to optimize the resulting performance across programs. Three steps are effective in accomplishing this:

1. Return-on-Investment (ROI) analysis for each program;
2. Head-to-head tradeoffs (pair-wise comparisons and program-to-program compromises); and
3. Consider widely held performance targets, by program, and compare with Steps 1 and 2.

Step 1 is where incremental investments are tested for each program, near a budget level that reflects a nominal budget value, such as from recent history. For example, Figure 11.5 illustrates a curve of investment in Pavement versus the resulting performance. It appears that the amount of investment shown is providing near-maximum performance. Thus, adding more money to Pavement in this scenario, would be an investment that is past the point of diminishing return, and therefore should be challenged.

Figure 11.5 Sample Program Performance and Return-on-Investment



Step 2 is to directly compare the performance benefits of spending an incremental amount of money in one program versus another. This was discussed earlier regarding tradeoff analysis, where shifting funds from one program to another may result in a "favorable compromise," and the ROI from investing an incremental amount in one program may significantly outweigh the ROI possible in making an incremental investment another program. In other words, if taking money from Pavement will not result in a significant drop in performance for that program, and the same money spent in the Bridge program results in a high ROI for Bridges, then perhaps the money would be better spent there. The decision-makers will need to use their judgment to weigh these types of tradeoffs, in addition to performing the analysis described in Step 1.

Step 3 is critical in that program performance targets are set by the Transportation Commission, with input from the Statewide Transportation Advisory Committee. The setting of these targets gives voice to the citizens of Colorado, and guides the activities taken by CDOT as stewards of Colorado transportation assets. In Step 3, it is important to consider the performance objectives where there is widely held consensus for the future. This consensus may come from the reviews of the Statewide Transportation Plan or other input. For example, there may be a consensus regarding the need for more highway capacity or for a specific performance target for pavement on Interstates. Comparisons of the investments necessary to meet these various expectations together with the conclusions reached from Steps 1 and 2 should provide great insight regarding reasonable performance targets overall. In summary, decision-makers should be able to reach consensus on overall funds distribution and setting targets by following these three steps.

No. 9 – Strategic Management

CDOT is implementing the Plan, Do, Check, Act (PDCA) framework described in Section above as its approach to managing asset management. Several improvements will be implemented over the course of the next few years that will enhance the effectiveness of this framework significantly. These are described below for each phase of the framework.

Process Steps in the "Plan" Phase

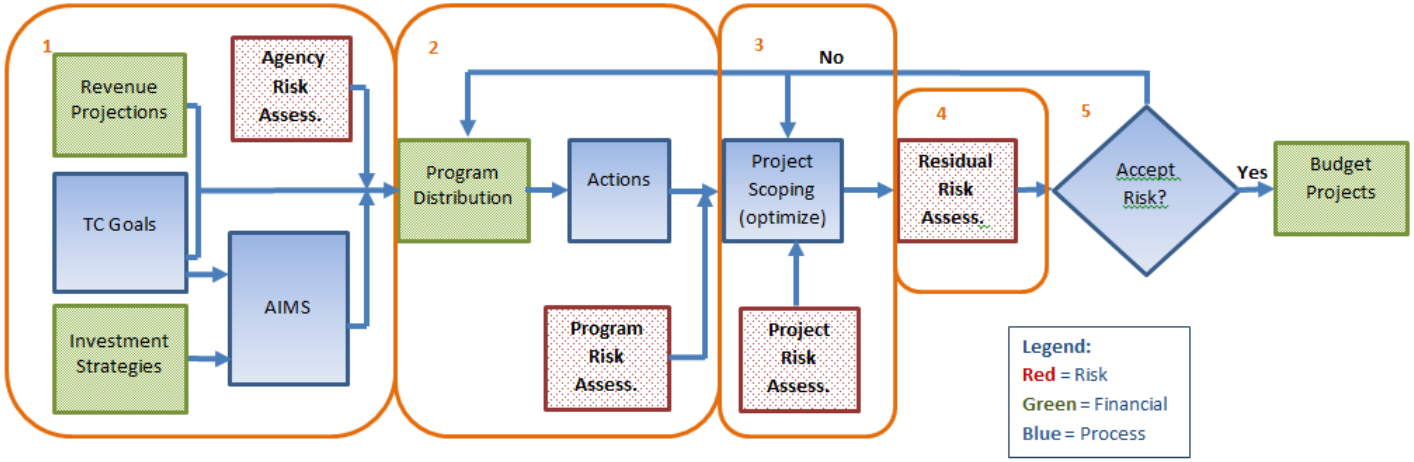
For the "Plan" phase, the first phase of the framework, the agency will be using an asset management decision process as depicted in Figure 11.6. The figure also shows how CDOT will integrate into the process. In addition to risk assessment, the process includes elements of program distribution, project scoping, budget tradeoffs, and final budgeting. This process is depicted in Figure 5.4 as the "Plan" part of the PDCA framework, and the detailed steps are listed here.

Going forward, the "Plan" phase will consist of the following steps:

1. Obtain revenue projections, including a range, over 10-year period;
2. Obtain Transportation Commission input on infrastructure performance goals (Policy Directive 14);
3. Review/update asset investment strategies;
4. Run asset management systems for a range of potential budget scenarios;
5. Perform agency risk assessment;
6. Utilize the Asset Investment Management System (AIMS) to determine cost versus performance for a 20-year horizon for each asset;
7. Perform investment tradeoffs (Delphi Workshop for some years);
8. Establish program budget distributions;
9. Perform program risk assessment;
10. Establish a list of project recommendations for each asset program;
11. Conduct project scoping and optimization:
    - Risk assessment at the project level;
    - Corridor considerations;
    - Synergies between Pavement, Bridge, and other assets; and
    - Sizing of projects.
12. Minimize project delivery risks (project mix, available resources, number of projects on the shelf, etc.);
13. Perform corridor-based residual risk assessment; and
14. Distribute funding to projects in the regions.

In addition to the contributions of the various management systems, the process incorporates AIMS, which is used to explore the relationship between program performance and funding levels, in support of program distribution decisions. Results from the risk analysis (see Section 7.0) are also a key component of the process. The process also uses results from the "Act" phase of the PDCA framework, such as performance goals and targets, and the Statewide plan. The process considers revenue projections in order to support program distribution decisions.

Figure 11.6 Risk-Based Asset Management Decision Process



Proposed Process for Incorporating Risk:

1. OFMB revenue projections, Transportation Commission goals and asset investment strategies are inputs into funding scenarios for the Asset Investment Management System (AIMS) to develop asset program distributions, which are considered along with agency level risks.
2. Asset distributions are used by the individual asset management systems to develop a list of improvement actions (also known as treatments).
3. The lists of improvement actions are used with asset specific risk assessments to develop projects.
4. When the program of projects is developed a corridor based residual risk analysis is performed to forecast the remaining risks to the system after these projects are completed.
5. If the residual risk is acceptable, the projects proceed to budgeting; if the residual risk is unacceptable (too many important corridors with unmitigated risk) then the risks are first fed back into project scoping to address, or to asset program distribution if funding targets need to be adjusted.

Source CDOT

Processes in the "Do" Phase

Once asset management projects are selected, several processes come into play. For example, the development and update of the Statewide Transportation Improvement Program (STIP) is an important one. CDOT currently utilizes a six-year STIP in programming projects into the future, and will be moving to an eight-year STIP on July 1, 2015.

To supplement the STIP, CDOT has developed a Project Pipeline framework. This newly developed capability allows an analyst to determine an estimated delivery date for a project depending upon the type of project, within a band of uncertainty and with a given confidence level. The analysis uses a probabilistic approach to estimating these delivery dates based on historical information regarding similar projects. This capability is very useful in scheduling projects and in delivering projects on time.

However, costs associated with funding uncertainties as well as other variables have also been identified as an important concern for CDOT, but this capability has yet to be developed at CDOT. CDOT's asset management implementation plan addresses the need to employ strategies that will reduce the losses associated with funding uncertainties and other risks associated with project delivery.

Processes in the "Check" Phase

An important feature of the PDCA framework is the discipline to "look back" and perform Plan versus Actual analysis. This would involve analysis of actual program funding and asset performance projections versus the actual performance results. This step in asset management is critical in order to determine whether, and how effectively, intended benefits of a variety of investments are paying off. CDOT has identified this as a capability requiring process development.

The "Check" capability is core to the PDCA framework, since this phase in the framework is what links the delivery of projects back to strategic decision-making regarding performance targets and the selection of future projects. The learning that takes place during the "Check" phase is the critical piece needed to provide continuous improvement and overall sustainability of the asset management effort. Therefore, the "Check" phase of PDCA is a major reason for establishing and implementing the PDCA framework.

Processes in the "Act" Phase

The "Act" phase is where the organization has the opportunity to adjust their targets regarding overall performance and performance by program. Some people refer to this phase as the "Adjust" phase because of the opportunity to reestablish overall goals and objectives. Information garnered from the "Check" phase is vital and needs to be packaged and provided to decision-makers in

order to be utilized to the fullest. This phase also provides an opportunity for CDOT to reassess its asset management investment strategies.

The processes and plans that come into play along with the results from the "Check" phase include:

- Department Policy Directives;
- Statewide Transportation Plan;
- Projected revenues and projected inflation rates; and
- Growth projections for system demand and citizen surveys.

These processes and plans are largely in place currently at CDOT and assist in adjusting targets each year. However, an essential part of the "Act" phase of the PDCA framework is target setting and this capability has been identified by CDOT as an area for development. The improvement would consist of an increased analytical rigor utilized in setting and adjusting targets based on optimizing the return on investment across all asset classes.

No. 10 – Communicate the Benefits of TAM

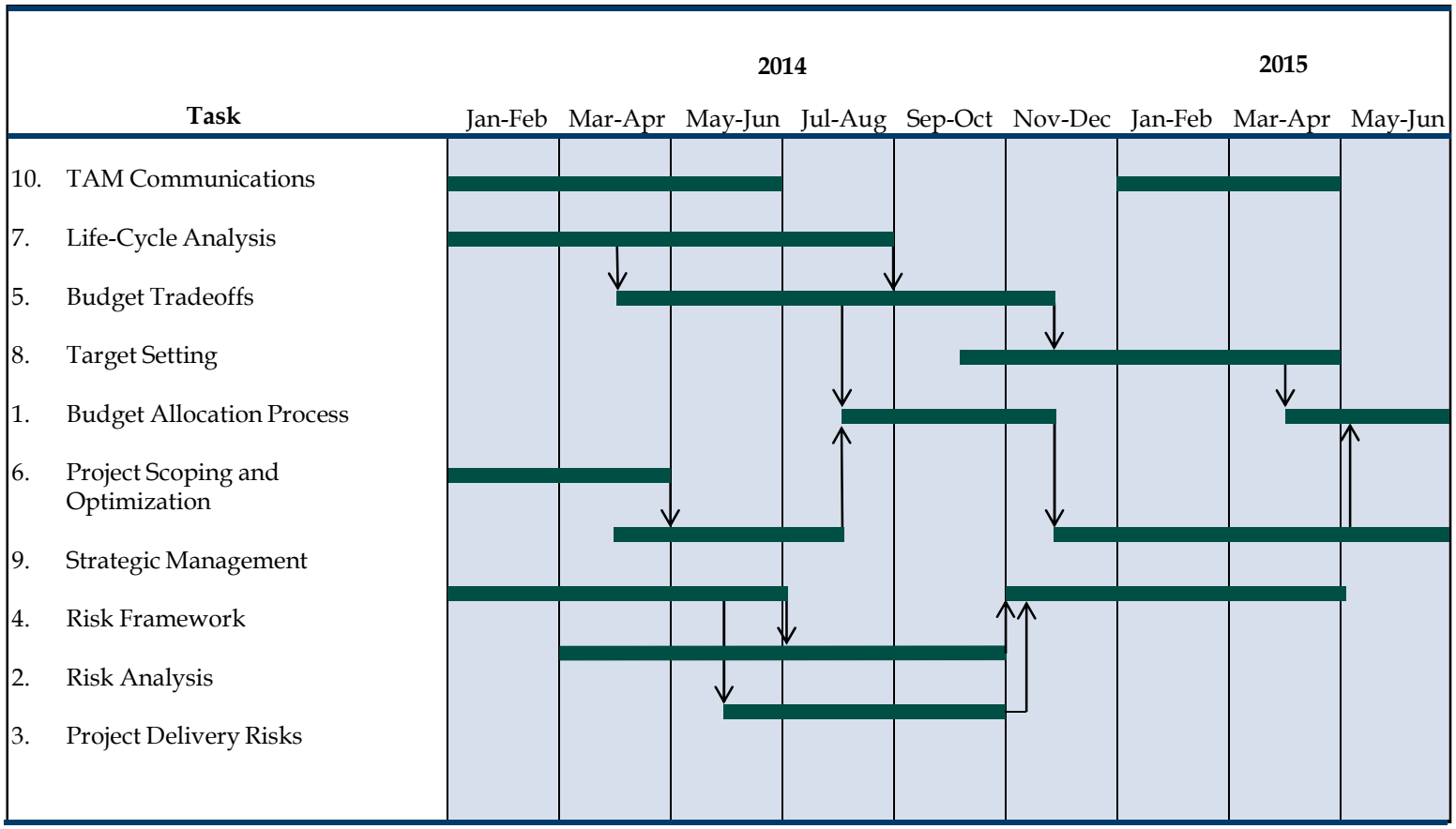
While CDOT has used asset management within assets for years, the shift from using funding formulas to providing funds to regions based on statewide need is new and requires significant change in how CDOT does business. The benefits to the citizens of Colorado are clear: if the condition of the highway system demonstrates a clear need in certain areas over the rest of the State, then more funds are directed to those areas. CDOT's mission is to "provide the best multimodal transportation system for Colorado that most effectively and safely moves people, good, and information," and asset management provides the foundation for the agency to meet its mission for all citizens.

11.5 IMPLEMENTATION SCHEDULE

Based on the dependencies described above, Figure 11.7 presents an overall implementation schedule. The arrows represent independencies between the major tasks. Table 11.1 identifies activities for each and identifies staff responsibility for each.

The dates defined in the table are ambitious and CDOT's management team recognizes that it will be necessary to address the highest priority items first. It is more important to take the time to complete these tasks correctly than to move quickly, so the two-year timeframe shown in the schedule is a suggested timeframe which may change.

Figure 11.7 Asset Management Implementation Plan
Overall Schedule



↓ ↑ Interdependency

Table 11.2 Gaps Recommended for Implementation, with Schedule

No.	Gap	Gap Dependencies (Prerequisites, etc.)	Resources Required	Project Lead	Begin Date	Deliver Date
1	Budget Distribution Process (FY 2017)	This capability will be improved by each asset documenting their process and tracking the status	Each asset manager is responsible for documenting how needs are assessed (incorporating risk) and funds are distributed for their asset.	Laurie Freedle/Kevin Henry	Aug 2014	Nov 2015
2	Risk Analysis	None	Staff time to identify, understand and rank risks to CDOT, and identify mitigation strategies	John Vetterling	Jan 2014	Oct 2014
3	Project and Program Delivery Risks	This capability will support the Strategic Management Framework	Managing delivery risks. This is part of the project pipeline and project portfolio management projects.	Richard Zamora	Jun 2014	Oct 2014
4	Establish Risk Framework	This capability will provide context for risk analysis	Staff time to suggest alternatives and SMT time to select and communicate chosen methodologies.	John Vetterling	Ongoing	Jun 2014
5	Analyze Budget Tradeoffs	Follows life cycle; this capability will support the asset budgeting process	CDOT is working towards cross-asset optimization, to better understand how to prioritize spending limited funds for the best overall ROI.	JoAnn Mattson/Laurie Freedle	Apr 2014	Nov 2014
6	Improve Project Scoping and Optimization	None – put this into place ASAP	Staff time to digest asset mgmt. concepts and determine how to apply them at every level, in a holistic manner to programs and projects.	Scott McDaniel/William Johnson	Ongoing	June 2014
7	Incorporate Life-Cycle Analysis	None – do ASAP, since this feeds other capabilities	Each asset manager must incorporate life cycle analysis into their asset management system and improve their understanding of how maintenance activities extend the life cycle of their assets.	JoAnn Mattson	Ongoing	Aug 2014
8	Target-Setting for RB AMP Update	Follows Tradeoff Analysis and supports Budgeting; Adjusted periodically	DTD and Staff Branches will work to make sure they understand direction from the TC and the SMT on this, and document accordingly.	DTD Planning: TBD	Oct 2014	Apr 2015
9	Strategic Management Framework	None – put this into place ASAP	Staff time from asset managers, regions, DTD, OFMB and Staff Branches, address the items listed in the Plan, Do, Check and Act framework.	Maria Sobota	Aug 2013	June 2015
10	TAM Benefits Communication	None – plan to provide communication regularly	Staff time to communicate change; and on the receiving side staff time to understand and implement the changes.	William Johnson	Aug 2013	Jun 2014

12.0 RB AMP Governance

This section addresses governance issues related to the RB AMP.

1. **Who "owns" the RB AMP?** Development of the RB AMP has been coordinated by the Transportation Performance Branch within the Division of Transportation Development, with significant input from Staff Services. A high level of collaboration will be required in order to implement many of the recommendations from the RB AMP. Moving forward, the TAM Committee is the owner of the RB AMP, and will determine the ongoing efforts to maintain and update the document
2. **How is the RB AMP related to other pertinent CDOT documents, such as the STIP, and Statewide Plan (SWP), and others?** The relationships between critical planning documents and decision-making processes at CDOT are illustrated and discussed in Section 6.0 of this document. The integration of these documents and processes is essential to the overall strategic management of assets and the sustainability of TAM at CDOT. In brief, the RB AMP incorporates financial information based on revenue planning and program distribution recommendations that are also included in CDOT's Statewide Plan. The RB AMP documents the processes for allocating these funds to projects, but does not include a list of specific projects. Specific projects are documented in CDOT's STIP.
3. **How often will CDOT update the RB AMP?** CDOT anticipates updating the RB AMP on a two-year cycle, incorporating information from the STIP and Statewide Plan, which are updated every four years. The first formal update is scheduled to being in April 2015, with a current target completion date of the fall of 2015. This two-year cycle is commensurate with the anticipated timeframe for implementing key TAM strategies, and determining the results from utilizing these new capabilities. It is anticipated that this update schedule will enable CDOT to update the RB AMP to reflect any additional MAP-21 requirements prior to the completion date defined in the legislation.

A. MAP-21 Requirements

This Appendix illustrates how the RB AMP addresses the asset management plan requirements in MAP-21.

Table A.1 MAP-21 Summary

MAP-21 Requirement	Refer to this Section of the RB AMP	How the RB AMP Address this Requirement
A state shall develop a risk-based asset management plan for the National Highway System to improve or preserve the condition to the assets and the performance of the system.	Entire document	The RB AMP is CDOT's risk-based asset management plan for preserving the condition of its assets. CDOT does not own and maintain the entire NHS. CDOT owns 90 percent of the NHS. The implementation plan in Section 11.0 identifies the need for CDOT to account for the entire NHS in future iterations of this document. Sections 2.0 discusses the importance of the RB AMP in terms of the performance of the system. Maintaining existing assets, which is the scope of the RB AMP, is a critical part of addressing system performance.
A state asset management plan shall include strategies leading to a program of projects that would make progress toward achievement of state targets for asset condition and performance of the National Highway System in accordance with section 150(d) and supporting the progress toward the achievement of the national goals identified in section 150(b).	Sections 4.1, 4.2, 5.1, 5.2, 5.3, 5.4, and 9.0	Section 4.1 establishes targets for asset condition. Sections 4.2, 5.1, 5.2, 5.3, and 5.4, explain the relationship between funding levels and achievement of these targets; and document how the budgeting process and programming process will help achieve these targets. Section 9.0 documents CDOT's asset management investment strategies. The strategies help to define the type, location and timing of asset management activities that CDOT implements. They are consistent with asset management best practices, will help CDOT achieve the condition targets established in this document, and are part of the overall strategic management of CDOT's assets. CDOT does not own and maintain the entire NHS. CDOT owns 90 percent of the NHS. The implementation plan in Section 11.0 identifies the need for CDOT to account for the entire NHS in future iterations of this document.
In develop a risk-based asset management plan, the Secretary shall encourage Sates to include all infrastructure assets with the right-of-way corridor in such plan.	Entire document	The RB AMP addresses pavement, bridges, traffic and safety devices, buildings, ITS equipment, fleet, runnels, culverts, and rockfall mitigation sites.
A state asset management plans shall include a summary listing of pavement assets on the National Highway System in the state, including a description of their condition.	Sections 3.1 and 11.2	The RB AMP addresses all CDOT-owned pavements. Although the State system goes well beyond the NHS, CDOT does not own and maintain the entire NHS. CDOT owns 90 percent of the NHS. The implementation plan in Section 11.0 identifies the need for CDOT to account for the entire NHS in future iterations of this document.
A state asset management plans shall include a summary list of bridge assets on the National Highway System in the state, including a description of their condition.	Sections 3.2 and 11.2	The RB AMP addresses all CDOT-owned bridges. Although the State network goes well beyond the NHS, CDOT does not own and maintain all NHS bridges. The implementation plan in Section 11.0 identifies the need for CDOT to account for the entire NHS in future iterations of this document.

MAP-21 Requirement	Refer to this Section of the RB AMP	How the RB AMP Address this Requirement
A state asset management plans shall include asset management objectives.	Section 1.0, Appendix B	CDOT defines asset management objectives in terms of target performance levels, as follows: **Bridges** – Maintain the percent of national highway system bridge total deck area that is not structurally deficient at or above 90 percent. – Maintain the percent of state highway total bridge deck area that is not structurally deficient at or above 90 percent. – Maintain the percent of bridges that are scour critical at less than 1 percent. – Maintain the percent of bridges with vertical clearance over Colorado State highways less than the statutory maximum vehicle height (14 feet-6 inches below 0.2 percent). – Maintain the percent of bridges with vertical clearance over Colorado State highways less than the minimum design requirement (currently 16 feet-6 inches) below 2 percent. – Maintain the percent of bridges posted for load at less than 0.1 percent. – Maintain the percent of bridges with load restrictions at less than 2 percent. – Maintain the percent of expansion joint length that is leaking at less than 10 percent. – Maintain the percent of bridge deck area that is unsealed or otherwise unprotected at less than 5 percent. **Highways** – Maintain 80 percent High/Moderate Drivability Life for Interstates based on condition standards and treatments set for traffic volume categories. – Maintain 80 percent High/Moderate Drivability Life for the National Highway System (NHS), excluding Interstates, based on condition standards and treatments set for traffic volume categories. – Maintain 80 percent High/Moderate Drivability Life for the State Highway System based on condition standards and treatments set for traffic volume categories. **Maintenance** – Maintain an overall maintenance level of service (MLOS) of B- for the State Highway System.
A state asset management plans shall include asset management measures.	Sections 3.0, 3.1 and 3.2	The RB AMP defines a performance measure for each asset type. All measures are described in Table 3.1. The key pavement measure is "percent of pavement with high or moderate drivability life." The key bridge measure is the "percent of deck are on bridges that are not classified as structurally deficient."

MAP-21 Requirement	Refer to this Section of the RB AMP	How the RB AMP Address this Requirement
A state asset management plans shall include a performance gap identification.	Section 4.1	CDOT defines the performance gap as the difference between fiscally constrained targets (performance levels that can be achieved over the 10-year plan horizon with the funds available) and aspirational targets (targets CDOT should strive for if revenues exceed projections). Table 4.1 presents all targets and defines the performance gap for each asset.
A state asset management plans shall include a life-cycle cost analysis.	Sections 6.0 and 9.0	CDOT's approach to life-cycle cost management varies significantly by asset type. For pavements, CDOT has incorporated life-cycle cost analysis into its pavement management software. CDOT uses this tool to provide its Regions with a recommended list of pavement treatments. The Regions use these recommendations as input into the project selection process. CDOT's policy is for at least 70 of final list of pavement projects to match recommendations from its pavement management software. For bridges, CDOT is currently updating its process for evaluating alternative bridge types and preservation actions so that it accounts for life-cycle cost considerations. In addition to influencing how CDOT selects treatments, many of the investment strategies defined in the RB AMP reflect life-cycle cost considerations.
A state asset management plans shall include a risk management analysis.	Sections 7.0 and 11.0	Through the development of the RB AMP, CDOT has developed an overall risk management framework, developed an initial risk register, and identified several next steps for enhancing its risk management practices, and further integrating them into the asset management planning process.
A state asset management plans shall include a financial plan.	Section 8.0	CDOT's asset management financial plan defines historic funding levels, indicates how much money is expected to be available for asset management over the next 10 years, and defines recommendations allocating these funds between the asset types. The financial plan also addresses financial sustainability. CDOT assesses financial sustainability by using overall system condition as a surrogate for overall value, and reviewing the impact of the implications of the recommended funding levels.
A state asset management plans shall include investment strategies.	Section 9.0	The RB AMP identifies investment strategies for CDOT's asset management program. The strategies help to define the type, location and timing of asset management activities that CDOT implements. They are consistent with asset management best practices and are part of the overall strategic management of CDOT's assets.
A state shall document the process used to develop the State asset management plan.	Sections 5.0, 6.0, 7.1, 8.0, 9.0, 10.1, and 11.1	Section 5.0 of the RB AMP describes CDOT's overall asset management framework, and defines key steps in the asset budgeting process. CDOT uses a strategic management process to organize its asset management efforts. The framework consists of four key steps (plan, do, check, act) that occur in a cycle. Additional details on the specific processes CDOT used to develop the RB AMP are provided throughout the document.

B. Policy Directive 14

I. COLORADO DEPARTMENT OF TRANSPORTATION		■ POLICY DIRECTIVE □ PROCEDURAL DIRECTIVE
Subject **Policy Guiding Statewide Plan Development**		**14.0**
Effective **TBD**	**Supersedes** 03/20/08	**Originating Office** **Division of Transportation Development & Office of Financial Management and Budget**

I. PURPOSE

This Policy Directive provides an overall framework for the transportation planning process through which a multimodal, comprehensive Statewide Transportation Plan will be developed that optimizes the transportation system by balancing preservation and maintenance, efficient operations and management practices, and capacity improvements. Policy Directive 14.0 performance objectives will direct distribution of resources for the Statewide Transportation Plan, the Statewide Transportation Improvement Program, and the annual budget. This Policy Directive is in alignment with the national goals in the 2012 federal transportation authorization law, MAP-21 (Moving Ahead for Progress in the 21st Century Act). This Policy Directive reflects CDOT's risk based asset management program and plan that incorporates a business approach intended to optimize investment for maintenance and preservation of CDOT assets based on both risk and performance assessment.

II. AUTHORITY

23 United States Code (U.S.C.) 134, 135 and 450, PL 112-141 ("Moving Ahead for Progress in the 21st Century" or "MAP-21), and its implementing regulations.

§ 43-1-106(8)(a), Colorado Revised Statutes (C.R.S.) Transportation Commission

§ 43-1-1103, C.R.S. Transportation planning

Transportation Commission Rules Governing the Statewide Transportation Planning Process and Transportation Planning Regions (2 CCR 601-22)

III. APPLICABILITY

This Policy Directive applies to all CDOT Divisions and Regions involved in implementing the Statewide Transportation Plan in cooperation with CDOT's planning partners: the 10 rural Transportation Planning Regions and the five Metropolitan Planning Organizations.

IV. DEFINITIONS

"Aspirational Objectives" are those objectives, or targets, toward which CDOT may strive should CDOT receive revenues beyond those projected.

"Drivability Life" is an indication in years of how long a highway will have acceptable driving conditions based on an assessment of smoothness, pavement distress, and safety. Drivability Life implements traffic based highway categories, and associated category drivability condition standards and allowed pavement treatments. Unacceptable driving condition is specific to each traffic based highway category and means drivers must reduce speeds to compensate for unsafe factors, navigate around damaged pavement, or endure intolerably rough rides.

"National Highway System" (NHS) is a federally designated system of roadways important to the nation's economy, defense, and mobility. The NHS includes Interstate highways as well as other roadways. Not all NHS roadways are part of the state highway system.

"Maintenance Level of Service" (MLOS) is a qualitative measure describing operational conditions on the roadway. Overall maintenance level of service is a combined grade for nine maintenance program areas. For snow and ice control, the LOS B level includes maintaining high levels of mobility as much as possible, and proactive avalanche control.

"Performance Measures" are the ways that direction toward a goal is measured.

"Performance Objectives" are the specific targets an organization intends to meet.

"Planning Time Index" is a comparison of the congested travel time at the 95th percentile to the free-flow time on Interstates and non-Interstate NHS congested corridors.

"Revenue Service Miles" are the miles transit vehicles are available to the general public.

"Serious Injuries" means evident injuries.

"Vehicle Miles Traveled" (VMT) is obtained by multiplying the Annual Average Daily Traffic (AADT) count by the length of the roadway segment.

V. POLICY

1. Policy. It shall be the policy of CDOT that the Statewide Transportation Plan and statewide performance objectives stated herein will direct distribution of financial resources to meet or make progress toward objectives in four goal areas: safety, infrastructure condition, system performance, and maintenance. Financial resources will be directed toward achieving the objectives within the first 10 years of the planning horizon (2016-2025). Projects will be selected to support the goals and objectives and will be included in the Statewide Transportation Improvement Program (STIP). Annual budget decisions will be guided by these performance objectives as well as CDOT's Risk Based Asset Management Plan. Prior to funding new initiatives, funds should be directed to achieving the objectives in each area while

recognizing constraints on some funding sources. Aspirational objectives will guide the use of funds received that are above baseline revenue projections.

2. Goals. CDOT transportation goals guide development of the multimodal Statewide Transportation Plan and of performance objectives. The goals are:

- SAFETY – Reduce traffic fatalities and serious injuries and work toward zero deaths for all users.

- INFRASTRUCTURE CONDITION – Preserve the transportation infrastructure condition to ensure safety and mobility at a least life cycle cost.

- SYSTEM PERFORMANCE – Improve system reliability and reduce congestion, primarily through operational improvements and secondarily through the addition of capacity. Support opportunities for mode choice.

- MAINTENANCE – Annually maintain CDOT's roadways and facilities to minimize the need for replacement or rehabilitation.

3. Performance Measures and Objectives. Performance measures describe how statewide success will be evaluated and performance objectives establish statewide achievement levels which are used to direct investment decisions primarily focused on a 10-year planning horizon (2016-2025). Explanations of how the objectives will be measured and budget categories that fund the four goal areas - Maintain, Maximize, Expand, and Pass-Through Funds/Multi-Modal Grants - are listed below with the appropriate goals.

a) SAFETY:
Safety objectives are mostly stated in a five-year average so that the trend can be evaluated (current five-year averages are based on data from 2008-2012). The budget categories that fund Safety are Maintain, Maximize, and Expand.

MEASURES:
- Number of fatalities
- Fatalities per vehicle miles traveled (VMT)
- Number of serious injuries
- Serious injuries per VMT
- Economic impact of crashes

OBJECTIVES:
- Achieve a five-year annual average reduction of 12 in the number of fatalities.
- Achieve a five-year annual average fatality rate of 1.00 per 100 million VMT.
- Achieve a five-year annual average reduction of 100 in the number of serious injuries.
- Achieve a five-year annual average serious injury rate of 25 per 100 million

VMT.

- Reduce the economic impact of crashes annually by 1% over the previous calendar year.

ASPIRATIONAL OBJECTIVE:

- Achieve a five-year annual average fatality rate of 0.98 per 100 million VMT.

b) INFRASTRUCTURE CONDITION:

The infrastructure condition objectives for highways and bridges are intended to be achieved or maintained over the first 10 years of the planning horizon (2016-2025). The budget category that funds Infrastructure Condition is Maintain.

(1) Bridges

MEASURES:

- Condition of National Highway System (NHS) bridges
- Condition of state highway bridges
- Risk-Based Asset Management Plan Goals for bridges

OBJECTIVES:

- Maintain the percent of NHS bridge total deck area that is not structurally deficient at or above 90%.
- Maintain the percent of state highway total bridge deck area that is not structurally deficient at or above 90%.
- Meet bridge goals in the Risk-Based Asset Management Plan.

ASPIRATIONAL OBJECTIVES:

- Achieve the percent of NHS bridge total deck area that is not structurally deficient at or above 95%.

(2) Highways

MEASURES:

- Pavement condition of the Interstate System
- Pavement condition of the NHS, excluding Interstates
- Pavement condition of the state highway system
- Risk-Based Asset Management Plan Goals for pavement condition

OBJECTIVES:

- Achieve 80% High/Moderate Drivability Life for Interstates based on condition standards and treatments set for traffic volume categories.
- Achieve 80% High/ Moderate Drivability Life for NHS, excluding Interstates, based on condition standards and treatments set for traffic volume categories.
- Achieve 80% High/Moderate Drivability Life for the state highway system

based on condition standards and treatments set for traffic volume categories.
- Meet pavement condition goals in the Risk-Based Asset Management Plan.

ASPIRATIONAL OBJECTIVES:
- Achieve pavement condition level of 90% High/Moderate Drivability Life for Interstates based on condition standards and treatments set for traffic volume categories.
- Achieve pavement condition level of 90% High/Moderate Drivability Life for NHS, excluding Interstates, based on condition standards and treatments set for traffic volume categories.

(3) Other Roadway Assets

MEASURE:
- Risk-Based Asset Management Plan Goals (for culverts, tunnels, walls, and rock fall mitigation)

OBJECTIVE:
- Meet Risk-Based Asset Management Plan Goals

(4) Transit

MEASURE:
- Transit Asset Condition

OBJECTIVES:
- Maintain the percentage of vehicles in the rural Colorado transit fleet to no less than 65% operating in fair, good, or excellent condition, per Federal Transit Administration definitions, beginning with the baseline established in September 2014.
- Ensure that all CDOT transit grantees have Asset Management Plans in place for state or federally funded vehicles, buildings and equipment by 2017.

ASPIRATIONAL OBJECTIVE:
- Increase the percentage of vehicles in the rural Colorado transit fleet to no less than 70% operating in fair, good, or excellent condition, per Federal Transit Administration definitions, beginning with the baseline established in September 2014.

c) SYSTEM PERFORMANCE:

The system performance objectives for Interstates, NHS and State Highway system are intended to be achieved within the first 10 years (2016-2025) of the planning horizon. The system performance objectives for transit begin in 2012 either for a five-year rolling average or as the baseline year. The budget categories that fund System Performance are Maximize, Expand, and Pass-Through Funds/Multi-Modal Grants.

(1) Interstates, NHS and State Highway system

MEASURES:

- Interstate Performance – Planning Time Index (PTI) for the Interstates
- NHS Performance – PTI for the NHS system, excluding Interstates
- Traffic Congestion – Minutes of delay on congested segments of the state highway system

OBJECTIVES:

- Maintain a statewide PTI of 1.25 or less for congested segments on Interstates.
- Maintain a statewide PTI 1.25 or less for congested segments on NHS roadways, excluding Interstates.
- Maintain daily travel time delay on congested segments of state highway corridors at or below 22 minutes of delay per traveler per day.

ASPIRATIONAL OBJECTIVES:

- Achieve a statewide Planning Time Index (PTI) of 1.2 or less for the Interstates.
- Achieve a statewide PTI of 1.2 or less for the NHS roadways, excluding Interstates.
- Achieve a daily travel time delay on congested segments of state highway corridors below 17 minutes of delay per traveler per day.

(2) Transit

MEASURES:

- Transit Utilization – Ridership statewide and by subcategory: small urban and rural
- Transit Connectivity – Revenue service miles provided

OBJECTIVES:

- Increase ridership of small urban and rural transit grantees by at least an average of 1.5% statewide over a five-year period beginning with 2012.
- Maintain or increase the total number of revenue service miles of regional, inter-regional, and inter-city passenger service over that recorded for 2012.

ASPIRATIONAL OBJECTIVES:

- Increase ridership of small urban and rural transit grantees at least an average of 1.7% annually over a five-year annual average beginning with 2012.
- Increase the statewide total number of revenue service miles of regional, inter-regional, and inter-city passenger service by at least an average 1.7% over a five-year period beginning with 2012.

d) MAINTENANCE:
Maintenance objectives are established based on annual funding levels and measured annually. The budget category that funds Maintenance is Maintain.

MEASURES:
- Level of Service (LOS) for snow and ice removal
- Overall Maintenance Level of Service (MLOS) for the state highway system

OBJECTIVES:
- Maintain an LOS B grade for snow and ice removal.
- Maintain an overall MLOS B- grade for the state highway system.

ASPIRATIONAL OBJECTIVES:
- Achieve a LOS B+ grade for snow and ice removal.
- Achieve an overall Maintenance LOS B grade for the state highway system.

4. Planning Principles. The planning principles describe how CDOT conducts business in carrying out the statewide transportation planning process.

a) Customer Focus. Improve customer service and satisfaction by focusing on the priorities identified by the public. Strengthen transparency and accountability by ensuring the public has multiple ways of learning about and participating in multimodal transportation planning and regional and statewide transportation decision making.

b) Partnerships. Collaborate with CDOT planning partners to build consensus for the integration of local, regional and statewide transportation priorities in the multimodal Statewide Transportation Plan and to reach data-based multimodal transportation planning solutions. Partner with other agencies and the private sector to leverage resources and to augment public funds.

c) Performance-Based Planning and Programming. Use a performance-based planning and programming approach in developing a multimodal Statewide Transportation Plan that aligns with MAP-21 national performance goals. Program projects in support of those goals and CDOT objectives and in alignment with the risk based asset management plan. Address both the 10-year and long range planning horizons.

d) Financial Planning. In cooperation with CDOT planning partners, and in recognition of declining revenues and increasing costs, develop reasonable Revenue Projections and a Program Distribution method that optimize the use of funds in addressing critical transportation needs. Utilize financial scenarios in the Plan in order to be prepared for different levels of future funding.

e) Freight Movement and Economic Vitality. Recognizing that Colorado's transportation system constitutes a valuable resource and a major public and private investment that directly affects the economic vitality of the state, enhance Colorado's economic

competitiveness by supporting measures that facilitate freight movement and promote state, regional and local economic goals.

f) Environmental Sustainability. Incorporate social, economic, and environmental concerns into the planning, design, construction, maintenance, and operation of a state multimodal transportation system. Support coordinated decision making that balances transportation, land and resource use, and quality of life needs. Promote a transportation system that minimizes impacts to and encourages preservation of the environment, and follows the CDOT Environmental Stewardship Guide. Provide a sustainable transportation system that meets existing needs without compromising the ability to provide for the future.

VI. IMPLEMENTATION PLAN

This Policy Directive will be implemented by the Division of Transportation Development, with the Office of Financial Management and Budget, and in collaboration with CDOT Divisions and Regions. Funds will be directed to budget categories to support accomplishment of the objectives. The Transportation Performance Branch will report annually on performance of the transportation system to track progress toward objectives. The Division of Transportation Development will review and update or reaffirm this Policy Directive with each Plan update cycle in collaboration with the Office of Policy and Government Relations.

VII. REVIEW DATE

This directive shall be reviewed on or before December 2018.

_____ _____

Secretary, Transportation Commission Date of Approval

C. CDOT Guidance for Asset Management

Risk-based transportation asset management is intended to achieve statewide performance targets given our limited funding while considering the likelihood and consequences of events impacting CDOT's assets. CDOT's Risk-Based Asset Management Plan is a living document that describes how asset management occurred in the past, how improvements to the asset management program are being made in accordance with MAP-21, and provides an implementation plan directing efforts to making better life-cycle decisions for assets. Transportation Asset Management (TAM) efforts are already underway at CDOT; this Guidance provides direction regarding the risk-based asset management process as formal asset management structure, policies, and procedures are developed.

Elements of TAM have been used at CDOT for years. In annual maintenance, levels of service (MLOS) are projected statewide at various funding levels and CDOT's decision-makers are able to prioritize between nine maintenance program areas, including Snow and Ice Removal and Traffic Services. The Bridge Enterprise exemplifies how statewide analysis drives investment in the most deficient bridges across the State using empirical, performance outcome-based project selection. The objective of risk-based asset management is to optimize statewide investments to keep our entire system safe and efficient.

Which Assets Does This Guidance Apply To?

The Division of Transportation Development – Transportation Performance Branch Manager (TPPBM) coordinates CDOT's asset management efforts. The TPBBM is directed by the Transportation Commission Asset Management Committee (TC-AM), and works closely with the Transportation Asset Management Oversight Committee (TAM OC), as the lead staff support and chair, to ensure asset management procedures are developed and executed. The following table includes the current asset categories that fall under this guidance.

Asset Programs	Asset Manager
Bridge	Staff Bridge Engineer
Buildings	Maintenance and Operations Branch Manager/Property Management Program Manager
Culverts	Staff Bridge Engineer
ITS	ITS Director
MLOS	Maintenance and Operations Branch Manager
Surface Treatment	Materials and Geotechnical Engineer
Landslide and Rockfall Mitigation	Materials and Geotechnical Engineer/Geotechnical Program Manager
Roadway Equipment/Fleet	Maintenance and Operations Branch Manager/Equipment Manager
Tunnels	Staff Bridge Engineer
Walls (TBD for FY 2015)	Staff Bridge Engineer

Not all CDOT programs are part of the asset management program. The table below lists all of the current programs as contained in the CDOT FY 2014/2015 budgets.

FY 2014 Budget Category	FY 2014 Budget Program Category	FY 2015 Asset Management-Based Distribution and Project Selection?
Maintain- CDOT Performed Work	Planning and Scheduling	Yes- MLOS
	Roadway Surface	Yes- MLOS
	Roadside Facilities	Yes- MLOS
	Roadside Appearance	Yes- MLOS
	Traffic Services	Yes- MLOS
	Structure Maintenance	Yes- MLOS
	Snow and Ice Control	Yes- MLOS
	Material, Equipment and Buildings	Yes- MLOS
	Tunnel Activities	Yes- MLOS
Maintain- Contracted Out Work	Surface Treatment	Yes- Surface Treatment
	Bridge On-System Construction	Yes- Bridge
	Bridge Inspection and Management	Yes- Bridge
	Rockfall Mitigation	Yes- Rockfall Mitigation
	Highway Safety Improvement Program	No
	Railway-Highway Crossing Program	No
	Hot Spots	No
	Traffic Signals	No, but future
	FASTER- Safety Projects	No
Maintain- Capital Expenditure	Roadway Equipment	Yes
	Capitalized Operating Equipment	No, but future
	Property	Yes, Buildings
Maximize- Contracted Out Work	Safety Education	No
	ITS Maintenance	Yes- ITS
	ITS Capital Replacement (not a dedicated funding program)	Yes
	Congestion Relief (Courtesy Patrol)	No
	Regional Priority Program	No
Maximize- Capital Expenditure	ITS Investments	No
Expand	Various	No
Deliver	Various	No
Pass-Through Funds/ Multimodal Grants	Various	No
TC Contingency and Debt Service	Various	No

Funding Distribution between Asset Categories

To receive continued RAMP Asset Management funding, asset programs must demonstrate improvements to their individual asset management systems and analysis tools and techniques

through the efforts of CDOT's Asset Management Working Committee and the Asset Investment Management System (AIMS).

Development of asset management budgets is a collaborative effort of engineering, planning and finance. Proposed funding levels for each asset category are set statewide using a "Delphi" method tradeoff exercise. The Delphi method is a facilitated group activity that allows participants to propose and discuss funding levels through iterative rounds to come to a consensus on how to distribute funding among eligible assets (the long-term use of the Delphi method will be reviewed in 2014). The funding levels are then reviewed by the TC-AM Committee. Once the TC-AM Committee approves the levels, the recommendation is sent to the full Transportation Commission for approval as part of the Draft Budget. To help coordinate project planning, asset managers are providing each region a draft planning budget with which to establish fiscal constraint in project planning.

Project Selection

While it is recognized that the current systems used to analyze each of the asset program categories are at various levels of maturity, each asset program must move measurably toward a more risk-based, performance-driven asset management approach for subsequent budgeting. The transition from regional allocation of funding to statewide prioritization of projects requires headquarters and region staff to work collaboratively to enable regions to properly plan for design and construction. Projects are selected collaboratively by asset managers and region staff utilizing the asset management principles specific to each asset category. Once the project have been selected the regions will work with OFMB to get projects STIP'ed.

Asset management project selection must include the following principles:

- Quantify risks associated with different levels of asset investment.
- Utilize lowest life-cycle cost approaches in all asset classes-always seeking the best value for CDOT's investments. (MLOS will continue to incorporate life cycle costs where practical).
- Incorporate not only sound engineering principles but also rational financial principles, including return on investment and net present value where appropriate.
- Asset managers will leverage their life cycle, performance-driven statewide models and work with region staff to determine optimal investments for their existing assets.
- Statewide pools will provide the budget for individual projects in the regions.
- Once asset management models can sufficiently recommend multiple years of prioritized projects, those projects will be evaluated by headquarters and region staff and then STIP'ed accordingly by the regions. This is similar to the Bridge Enterprise process today. It is anticipated that the FY 2016 Delphi process in January will be the last single year budget-setting effort for the asset management programs in this guidance.
- Report on investment outcomes so that the Transportation Commission and Asset Management Committee can make informed budgeting decisions within and across asset classes.

For surface treatment projects in particular, the following policies also apply:

- No portion of the FY 2015 surface treatment program will be reserved by headquarters or the regions for a "maintenance" pool. However, as the FY 2015 program is developed, asset managers and region engineers will utilize cost-effective Bituminous Surface Treatments (BST) and other thin treatments where appropriate.

- Regions may continue design work for surface treatment projects on Interstate and high-volume NHS routes. Other pavement design work should proceed with caution and recognize new approaches. For low-volume highways (highways with less than 2,000 vehicles per day and less than 100 trucks per day) cost-effective thin surface treatment should be considered to improve the drivability of the road surface. Any treatment with work beyond the Pavement Treatment Guide limits for these low-volume roads should be coordinated through the Materials and Geotechnical Engineer, who will work as needed with Staff Branches to determine if it is a project that can be funded with the treatment considered.
- Any proposed project on a low-volume road beyond the Pavement Treatment Guide limits must be submitted to the Chief Engineer as a request for review with a justification memo as to why the project is recommended and why the selected treatment is optimal.

Moving Forward

MAP-21 requires each state to develop a risk-based asset management plan, providing inventory and condition data for roads and bridges, along with a financial plan and including an approach to addressing risk. CDOT's Risk-Based Asset Management Plan (RB AMP) incorporates inventory and condition data from additional assets where available and will be updated upon MAP-21 rules promulgation and periodically thereafter. CDOT's AIMS tool provides the capability to generate budget-based performance curves for each asset where inventory and condition data are available.

As CDOT continues building its asset management program, there are a number of expectations for the asset managers and the asset management teams in each category. They include:

- Each asset management team must develop and maintain a list of asset management projects and/or equipment, furnished by asset managers, and provide progress on those projects. CDOT's new Project Portfolio Management initiative led by AECOM may coordinate this.
- Asset managers will be expected to present at the January 2014 Delphi Workshop their enhanced asset management systems and to demonstrate the progress and results of FY 2014 RAMP and Baseline Budget investment.
- Asset managers must work as partners in the continued development of the RB AMP and AIMS efforts- various asset categories must achieve consistency in presentation of information to CDOT's decision-makers, including performance forecasts, budget and expenditure reports, mapping, and other items determined by the TAM OC.
- For risk-based asset management to succeed, it is critical to have consistent participation from every CDOT region. Each region currently has representation on the Transportation Asset Management Working Committee (TAM WC) and should continue to participate in the decisions and activities of that committee.

The TAM WC should begin to identify the vast array of existing policies and procedures, including Chief Engineer memos, policy directives, procedural directives, and a variety of manuals such as the pavement design manual that need to be pulled together under a single asset management structure.

D. Bridge Enterprise Project Prioritization Memorandum

This memo documents the procedures used by the Bridge Enterprise in project selection.

COLORADO BRIDGE ENTERPRISE
Memorandum

Colorado Bridge Enterprise
4201 East Arkansas Avenue
Denver, Colorado 80222

DATE: May 3, 2013

TO: Bridge Enterprise Board of Directors

FROM: Tim Harris, CBE Chief Engineer
Josh Laipply, CDOT Bridge Engineer

SUBJECT: Bridge Prioritization Plan Update

BRIDGE ENTERPRISE WORKSHOP

The workshop will provide the CBE Board of Directors with an update regarding the development and implementation of the Bridge Prioritization Plan.

The Prioritization Plan serves as an objective scoring system whereas both **quantitative** and **qualitative** criteria are taken into consideration to determine which FASTER eligible bridge(s) represent the best use of available funding. All current un-programmed bridges and future FASTER eligible bridges will be scored and assigned a numerical value (or ranking) that can be compared to each other to ensure that available funding is being applied to the most relevant structure.

The workshop shall address the following topics:

- Survey questionnaire and survey data results.
- Establishment of scoring worksheet and associated weighting of major-criteria and sub-criteria.
- Development of the Prioritization Plan Logic Summary and corresponding selection workflow diagram.
- Testing of the scoring worksheet using current FASTER eligible bridges to ensure that criteria weighting system is advancing structures commensurate with expected results.
- Review of sample test results.
- Reclassification of current un-programmed bridges.

In support of this workshop, the following attached documents shall be reviewed:

- Prioritization Plan Logic summary
- Survey data results
- Scoring worksheet and scoring criteria weighting breakdown
- Selection workflow diagram
- Sample test results

Colorado Bridge Enterprise

Prioritization Plan - Logic Summary

April 23, 2013

Introduction

The Prioritization Plan is a tool to aid decision-makers in establishing which projects are best suited to be programmed by meeting CDOT's and Bridge Enterprise's goals. The process is a means to help generally prioritize and rank structures in order of importance based on the quantitative and qualitative factors. The prioritization plan converts these factors for each structure to weighted numerical values. The combination of factors will determine a final score for each structure. These scores rank structures in the program in a consistent method and help the Bridge Enterprise allocate resources in a more effective, transparent manner.

Definitions

Bridge Designation:

- Structurally Deficient is used to describe a bridge that has one or more structural defects that require attention.
- Functionally Obsolete is used to describe a bridge that is no longer compliant by design to the current code. Examples of functionally obsolete include: not having enough lanes to accommodate traffic flow, inadequate shoulder width, etc.

Sufficiency Rating: Bridge sufficiency is a method of evaluating highway bridge data by calculating four separate factors to obtain a numeric value that is indicative of a bridge's ability (sufficiency) to remain in service. The four factors include: structural adequacy and safety, serviceability and functional obsolescence, essentiality for public use and special reductions. The result of this method is a percentage in which 100 percent would represent an entirely sufficient bridge and zero percent would represent an entirely insufficient or deficient bridge. The lower the sufficiency rating the higher the prioritization plan score.

Bridge or Structural Condition: This section examines the condition rating of different structure components. An element receives a high prioritization value if the structure is posted for reduced capacity, has insufficient vertical clearance, and/or the condition rating is considered poor or worse, or receives a score less than or equal to 4 on the Structure Inspection and Inventory Report (SIA report).

Average Daily Traffic (ADT): ADT is defined as the average number of bidirectional vehicles passing on a specific bridge in a 24-hour period. The higher the ADT is on the structure, the higher the prioritization score.

Percent Truck Traffic (%TT): The %TT definition is simply the percentage value that shows the percentage of average daily traffic that is truck traffic. The higher the %TT is on the structure, the higher the prioritization score.

Bridge Importance: This section highlights the type of traffic the structure carries, its importance locally and within the region, designation on the National Highway System (NHS) or historical standing. The structure can be more than one of the sub-criterion listed in this section.

- The NHS as defined by the Federal Highway Administration (FHWA) as the Interstate Highway System as well as other roads important to the nation's economy, defense, and mobility.
- Primary access to a local community will be determined by the length of detour needed during construction.
- Economic strategic corridor is defined as a corridor that is deemed important to movement of freight, tourism, agriculture, oil and gas, etc. and is officially designated by the CDOT Division of Transportation Development (DTD) office.
- Historical significance is determined if the structure is on the Historic Bridge List or candidate.
- Significant pedestrian or bike crossing is determined by the type of service for the on-system bridge and through discussions with the region.

Economic Factors/Impacts: This section examines the cost-benefit of completing a particular bridge by comparing rehabilitation versus replacement, the economy of scale by combining the structure with a companion bridge or roadway improvement, and/or rehabilitation or replacing a structure that has significant long-term maintenance or interim repair costs. This section will need the most discussion with the region to determine what funds the region can contribute to work outside of Bridge Enterprise and what their needs are.

Other Factors or Issues: Factors other than the current criteria and sub-criteria may have a significant impact on the decision to program a project. The sub-criteria can be both positive and negative and result in up to a 5 point modification in the total point score for the subject bridge. Examples of other factors include:

Positive Factors	Negative Factors
• Regional or local funding contributions to project • Accelerated Bridge Construction candidate • Innovative Contracting Method candidate	• Issues with an Intergovernmental Agreement • Limited funding resources for entire project • Right-of-Way constraints • Extensive environmental or railroad issues

Reference Documents: Documents referenced in this summary include: the Prioritization Plan Scoring Worksheet, the Prioritization Plan Workflow Document, the Economic Strategic Corridor Map, and the Structure Inspection and Inventory Report. These documents will be used in the implementation of the Prioritization Plan.

E. List of Acronyms

AASHTO – American Association of State Highway Transportation Officials

AIMS – Asset Investment Management System

ATR – automatic traffic recorder

BMS – Bridge Management System

BST – Bituminous Surface Treatments

CBE – Colorado Bridge Enterprise

CAN – Change Agent Network

CCTV – Closed Circuit television

CDOT – Colorado Department of Transportation

CMAQ – Congestion Mitigation and Air Quality

CORE – Commonly Recognized Element

DL – Drivability Life

DVMT – Daily Vehicle Miles Traveled

EMAC – Equipment Management Advisory Committee

ESAL – Equivalent Single-Axle Load

EJMT – Eisenhower-Johnson Memorial Tunnel

FASTER – Funding Advancement for Surface Treatment and Economic Recovery

FO – Functionally Obsolete

GIS – Geographic Information Systems

GSP – Gross State Product

GVW – Gross Vehicle Weight

HLT – Hanging Lake Tunnel

HOV/HOT – High-occupancy vehicle/high occupancy toll

HUTF – Highway User Tax Fund

HVAC – Heating, ventilation and air conditioning

IRI – International Roughness Index

ITS – Intelligent Transportation Systems

MAMS – Multi Asset Management System (former name of system now called AIMS)

MAP-21 – Moving Ahead for Progress in the 21st Century Act

MLOS – Maintenance Levels of Service

MPA – Maintenance Program Area

NBI – National Bridge Inventory

NBIS – National Bridge Inspection Standards

NHI – National Highway Institute

NHS – National Highway System

PDCA – Plan, Do, Check, Act

PMS – Pavement Management System

PD 14 – Policy Directive 14

RAMP – Responsible Acceleration of Maintenance and Partnerships

RB AMP – Risk-Based Asset Management Plan

ROI – Return on Investment

RSL – Remaining Service Life

RTD – Regional Transportation Director

SD – Structurally Deficient

STIP – Statewide Transportation Improvement Program

SWP – Statewide Transportation Plan

TAM – Transportation Asset Management

TAM OC – Transportation Asset Management Oversight Committee

TAM WC – Transportation Asset Management Working Committee

TC – Transportation Commission

TTI – Travel Time Indicator

VMS – Vehicle message sign

VMT – Vehicles Miles Traveled