



Governor Hickenlooper, and updated in 2020 under the leadership of current Governor Polis. This plan looks at natural threats and disasters in Colorado including floods, droughts, earthquakes, tornadoes, wildfires, and landslides. The Statewide Resiliency Framework serves two purposes: to show “a commitment from the State to identify and implement strategies to strengthen and increase resiliency” and to outline “guiding principles and tools for community stakeholders and calls for a collective commitment to partnership and action.”<sup>2</sup>

## Resilience Initiatives at the Agency

### Interstate 70 Corridor Risk and Resilience Pilot

CDOT started the Interstate 70 Corridor Risk and Resilience (R&R) Pilot in 2015 to examine the Interstate 70 highway system’s ability to serve traffic demand during times of natural disaster. Completed in 2018, one of the goals of this Pilot was to investigate whether the findings could be useful to CDOT “operations, planning, asset management, maintenance, and engineering design and how the data generated can be incorporated into these management programs to reduce system risk and improve resiliency.”<sup>3</sup> CDOT worked with the Federal Highway Administration (FHWA) to assess how the system might perform under a range of physical hazards affecting the interstate, from rock fall to flooding. CDOT examined each asset along Interstate 70 to determine asset vulnerability and risk to infrastructure in cases where damage is incurred. This process also involved conducting a benefit cost analysis to determine the financial risk of potential damage to all assets along this corridor. The agency separated asset risks into two categories: the risk to the owner (the risk to CDOT to replace any damaged assets) and the risk to the user (the delay in a user’s trip caused by a road closure/route detour due to asset unavailability). CDOT incorporated the results of the asset vulnerability assessment from this R&R Pilot into its overall asset management program. From this study, CDOT has found that rock fall poses the highest financial risk to the owner (CDOT) and flooding poses the highest risk to the user (the public). CDOT used the Risk Analysis and Management for Critical Assets Protection (RAMCAP Plus) framework to identify Interstate 70’s most critical assets based on threats and vulnerability and identify those where damage would most severely impact the operation of the highway system as a whole (Table 1).

1) Asset Characterization	What assets exist and which are critical?	5) Threat Assessment	What is the likelihood that a terrorist, natural hazard or dependency/location hazard will occur to asset?
2) Threat Characterization	What threats and hazards should be considered?	6) Risk/Resilience Assessment	What is anticipated total risk and asset resilience?
3) Consequence Analysis	What happens to assets if a threat or hazard occurs? Expected asset losses, economic impacts, injuries, lives lost?		$Risk = Consequences \times Vulnerability \times Threat$ $Resilience = Service Outage \times Vulnerability \times Threat$
4) Vulnerability Analysis	What are asset vulnerabilities that would allow a threat or hazard to result in expected consequences?	7) Risk/Resilience Management	What options are there to reduce risks and increase resilience? How much will each mitigation measure reduce risk and increase resilience? How much does each mitigation measure cost? What is the calculated benefit/cost ratio?

Table 1. The RAMCAP Plus method in 7 steps.

Throughout the R&R Pilot, CDOT engaged multiple groups. Agency leadership formed an Executive Oversight Committee to guide higher-level decisions about the project. This Executive Oversight Committee was comprised of engineers, the head of the Planning Division, and FHWA. In addition, a Working Group was formed to represent each of the five geographic regions of CDOT. The Working Group comprised of headquarters staff, a hydraulics engineer, a planner, an

<sup>2</sup> For more information see:

<https://docs.google.com/a/state.co.us/viewer?a=v&pid=sites&srcid=c3RhdGUuY28udXN8Y29sb3JhZG91bml0ZWw8Z3g6MmRmMjlmMjMwOTBIMjNkYw> P. 1-2 Introduction – Resiliency in Colorado, Colorado Resiliency Framework.

<sup>3</sup> I-70 Corridor Risk and Resilience (R&R) Pilot, Colorado Department of Transportation, November 2017.

[https://www.codot.gov/programs/planning/documents/plans-projects-reports/reports/i70rnr\\_finalreport\\_nov302017\\_submitted\\_af.pdf](https://www.codot.gov/programs/planning/documents/plans-projects-reports/reports/i70rnr_finalreport_nov302017_submitted_af.pdf).

environmental expert, an expert in geotechnology, an expert in engineering design, and a traffic expert, among others. Working Group members were chosen intentionally to be reflective of the entire project life-cycle. The Working Group met for several full-day workshops during the R&R Pilot and has met monthly since that project's completion.

### **Agency Incorporation of Criticality**

CDOT defines criticality as reflecting “the importance of each asset to overall operations within CDOT’s network as related to system resilience only.”<sup>4</sup> To determine an asset’s criticality, the agency gives each asset a high, medium, or low weight. CDOT determines asset criticality using RAMCAP, which is a methodology using risk to analyze resilience of infrastructure. This method involves characterizing the asset by threats and hazards, conducting a consequence and vulnerability analysis, and assessing threats, risks, and resilience to that asset to determine the best risk and resilience management practice. The criticality model considers social, environmental, and economic factors including six variables that are weighted equally: traffic volume; roadway classification; economic value of tourism; economic value of freight; Social Vulnerability Index (SOVI) of the population; and system redundancy or lack thereof. The criticality model identifies about 21% of CDOT’s roadway system statewide as highly critical to system operations. Identifying criticality has allowed CDOT to pinpoint which roadways need immediate attention. This directs the agency to prioritize highly critical roadways when deciding on investment, where maintenance is needed, or where inspections should take place. The agency has recently used this approach to determine criticality of its culverts statewide, and to quantify where improvements make sense from a benefit cost perspective. A map of culvert criticality has been integrated into the State’s ArcGIS analysis. CDOT is working on incorporating criticality into asset replacement prioritization and added this approach into its TAMP, which CDOT submitted in the summer of 2019.

### **Risk and Resiliency Analysis**

CDOT has developed and documented a standardized R&R analysis process which also uses RAMCAP. This process is documented in a manual, adopted in 2020, with instruction and assumptions on how to conduct R&R analyses on CDOT assets in the future, with a goal of improving consistency of analyses across different regions of the State. In developing the manual, CDOT conducted outreach with subject matter experts (SMEs) throughout the agency to fine tune the process and assumptions used in the R&R pilot.

### **Policy Directive and Resiliency Integration Project**

In 2018, the Executive Oversight Committee and Transportation Commission adopted Policy Directive 1905: “Building Resilience into Transportation Infrastructure and Operations,” which grew out of a response to the 2013 floods in Colorado. This Policy Directive formalizes and encourages resilience activities at CDOT and gives the agency the ability to proactively manage risks and anticipate future challenges. The purpose of this Policy Directive is to implement resilience into transportation system practices and into all aspects of operations. This Policy Directive allows the Division of Transportation Development to be proactive in maintenance and operations to mitigate any potential future consequences. One of the goals of the Policy Directive was to adapt the agency to changing environmental conditions to provide continuous transportation service in Colorado. This Directive saves the State money, saves the public’s travel time, promotes timely access to markets, and benefits public safety. This Policy Directive applies to all operations of CDOT including all branches, regions, divisions, and offices, and applies to planning, design, engineering, asset management, maintenance, mobility operations, and enterprise operations.<sup>5</sup>

In early 2020, CDOT embarked on a Resiliency Integration Project to conduct five “proof of concept” case studies to investigate how the agency might better integrate resilience into all aspects of agency operations. The agency is taking

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<sup>4</sup> For more information see: <https://www.codot.gov/programs/environmental/transportation-environmental-resources-council-terc/presentation-6-8-17>, 3.

<sup>5</sup> For more information see: [https://www.codot.gov/programs/planning/documents/plans-projects-reports/projects/resilience\\_program/policy-directive-pd-1905.0](https://www.codot.gov/programs/planning/documents/plans-projects-reports/projects/resilience_program/policy-directive-pd-1905.0).

key findings from the case studies to map the agency's business processes and identify where resiliency can be added. The case studies focus on asset management, maintenance and operations, planning and project prioritization, the environmental process, and project scoping and design. Target completion for the project is the end of the 2021 calendar year. This will involve updating existing manuals or procedures and documenting findings about how resilience can be better integrated into day-to-day operations.

## Next Steps

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CDOT is finalizing plans for mitigating high risk culverts statewide. When this is complete, CDOT will run a benefit cost analysis on the suggested improvements to see where the agency's investment could be justified and request funding in cases where it is. CDOT will also continue working on a Resiliency Integration Project which began in early 2020.

## Resources

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- **CDOT's Risk and Resilience Webpage:**  
<https://www.codot.gov/programs/planning/cdot-resilience-program>.

This webpage has links to CDOT's risk and resilience pilot, various initiatives, partnerships, and resources.

- **Colorado's Resiliency Framework:**  
<https://coresiliency.squarespace.com/colorado-resiliency-framework>.

The State of Colorado outlines its resiliency framework in this document.

- **Colorado Resiliency Office Webpage:**  
<https://www.coresiliency.com/>.

This webpage has links to Colorado's Resiliency Framework, Playbook, and Planning Survey.

## Transportation Resilience and Durability Case Study Series

The Federal Highway Administration is developing a series of case studies exploring resilience and durability efforts at transportation agencies across the United States. The case studies are developed through in-depth interviews with a geographically diverse range of transportation agencies. These case studies explore how resilience and durability factor into various phases of transportation decision-making, the scales and types of resilience and/or durability projects at the agencies, and the types of resilience addressed.