

Executive Summary

The Colorado Department of Transportation (CDOT) established the Resilience Program in response to the devastating 2013 floods that caused over \$700 million in damages to transportation assets in the State. The extensive damage that resulted from the 100-year flood event prompted CDOT to prioritize preventative action against future events. The I-70 Risk and Resilience (R&R) Pilot project began in 2016 and was the State's first effort to systematically quantify risk to transportation assets from severe environmental events.

To better understand the current state of resilience research and best practices, several publications, existing resilience frameworks, and a case study were evaluated. CDOT's resilience practices and progress are then related to existing recommendations and best practices revealing that CDOT is a national leader in prioritizing resilience through their research and development of resiliency focused projects.

From 2018 to 2020, CDOT developed a comprehensive Risk and Resilience Analysis Procedure manual that establishes a robust methodology for quantifying risk to assets from potential threats that can be applied across the State. The I-70 R&R Pilot project data model was rerun using the methodology from the Procedure manual, which changed several assumptions from the initial model which are: increased unit costs for all asset types, increased vulnerability to assets from flood and rockfall events, simplified user cost model with modified closure days, and added clean-up costs. These refined assumptions caused substantial changes to both owner and user risk calculations.

In terms of owner risk, seven of the eight threat-asset pairs had substantial increases to annualized risk with the roadway-flood pairing showing the only decrease. Compared to the first round of data, owner risk increased by 904% with a total of \$52,022,486 due to increased unit costs and vulnerability. Most of the owner risk increase is due to substantial growth within the minor culvert-flood and roadway-rockfall pairings, accounting for over 600% of that increase.

User risk had an even split of threat-asset pairings increasing and decreasing in the second round. Projected closure days resulting from threat events was decreased for most assets, with the exception being bridges that had projected closure days increased 50% from 120 to 180 days. Despite reduced closure days per event the minor culvert-flood, bridge-rockfall, ptc's-rockfall, and roadway-rockfall pairings increased due to the changes in asset vulnerability. User risk increased by 425% from the first round with a total of \$806,126,618 generated with the refined assumptions.

The second round of data using the methodology developed in the R&R Procedure manual produced more realistic data than the first iteration, particularly in terms of owner risk. The first round of data generated only \$5,179,908 of annualized owner risk which many CDOT personnel thought was underestimating the risk. While the refined model undoubtedly produces better data, there is room for improvement moving forward. Some recommendations to improve the process are:

- Consider utilizing a rockfall methodology that considers both directions of travel independently much like the first round does with the east bound lanes experiencing greatly reduced risk as opposed to the westbound lanes from rockfall events.
- Improve the asset database to make sure risk is calculated using up to date numbers and to ensure that assets that currently generate no risk values due to missing attribute data are addressed.
- Evaluate the 13 bridge-rockfall pairs on an individual basis, as each segment is currently generating the same value regardless of length.
- Refine the vulnerability values periodically as more data becomes available in the future.

Recommendation #1



Separate east and west bound lanes of travel when calculating rockfall risk

Eastbound lanes of travel along I-70 experience less impact from most rockfall events

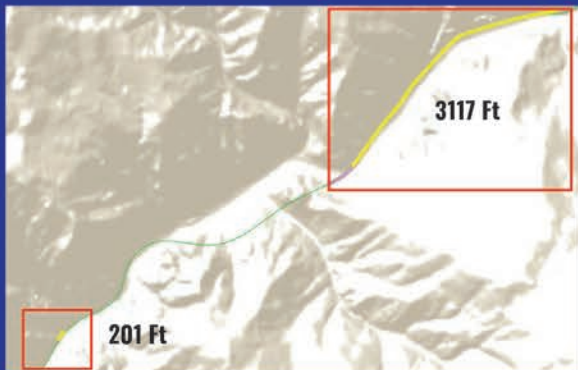
Recommendation #2

994 out of 2822 Assets did not generate any risk

Improve the asset database to make sure risk is calculated using up to date numbers

Majority of incomplete data is associated with minor culverts causing underreported risk values

Recommendation #3



Evaluate the 13 bridge-rockfall pairs on an individual basis, currently they generate identical risk values regardless of length

Recommendation #4

Vulnerability values have large impacts on both owner and user risk

Refine the vulnerability values periodically as more data becomes available in the future.

Uncertain vulnerability coefficients can easily lead to inflated or underreported risk values