



4R Framework for Identifying and Evaluating Resiliency in Transportation System Assets and Organizations

GEO HAZARDS

Geological events such as landslides and rockfall with the potential to cause damage to property, infrastructure, and the environment; loss of life; and economic losses. There is a risk of geotechnical failure that causes mobility and safety impacts, as well as increased asset management cost.



4R Attributes

- **Robustness:** The strength of an asset or a system to withstand relevant threats
- **Redundancy:** The presence of a backup system or plan
- **Resourcefulness:** Ability to identify, diagnose, and treat problems with available resources
- **Rapidity:** Ability to restore functionality in a timely way

Technical Examples

- CDOT uses ditches to protect assets from rockfall threats where space allow. In high-risk areas with limited space, such as Glenwood Canyon along I-70, alternative rockfall mitigation measures have been installed such as protection fences, draped wire mesh, and rockfall attenuators. These systems are designed to intercept falling rocks and prevent them from reaching the roadway. (Robustness)
- CDOT installs real-time geotechnical monitoring instruments such as inclinometers, piezometers, and strain gauges in landslide-prone areas. This ensures continuous data collection even if one sensor fails. (Redundancy)
- CDOT uses portable LiDAR scanners to map slopes and monitor active rockfall zones, enabling the agency to redirect crews and resources efficiently. (Resourcefulness/Rapidity)
- CDOT has dedicated Geohazard Program crews trained to respond to events like landslides, rockfalls, and debris flows. These teams are equipped with heavy-duty excavators, front loaders, and skid steers for rapid debris clearance. (Rapidity)

A Resilient Transportation Organization

- Has an organizational mindset of enthusiasm for challenges, problem solving, agility, flexibility, innovation, and taking opportunity.
- Understands interconnectedness and vulnerabilities across all aspects of agency function.
- Has established relationships, prearranged mutual aid arrangements, and regulatory partnerships.
- Has established response plans in place to mobilize when events occur.

A Resilient Transportation Asset

- Is designed to withstand and recover from unexpected events and challenges, recognizing that the possibility of failure can never be eliminated.
- Has parts, elements, systems, facilities, etc., that are substitutable, e.g., are capable of satisfying backup functional requirements in the event of disruption, degradation, or loss of functionality of the primary system.
- Includes equipment to monitor and alert to potential threats or failures before they occur. Sufficient materials are on hand to efficiently mobilize in case of emergency.
- Designed in such a way that disruptions are minimized, losses may be contained, and functionality can be restored rapidly.

Organizational Examples

- In areas prone to landslides, such as CO 145 near Telluride, CDOT works with local emergency managers to pre-position equipment (e.g., bulldozers, excavators) and crews for rapid debris removal. (Rapidity)
- CDOT installs automated rockfall detection systems, such as motion sensors and cameras. These systems notify CDOT crews of rockfall events in real-time, enabling rapid response and reduced roadway closure times. (Resourcefulness)
- Collaboration with U.S Geological Survey (USGS) ensures that CDOT implements robust rockfall mitigation systems, such as catchment fences, draped mesh, and rock sheds to protect highways like US 6 through Clear Creek Canyon. (Robustness)