Quantitative Method of Risk Assessment for Asset Management Programs

RISK AND RESILIENCE FOR HIGHWAYS

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Reactive vs. Proactive Risk and Resilience (RnR) Approach

Reactive (ER)

RnR for FHWA Emergency Relief (ER)

- Risk-based B/C analysis for betterment justification & funding
- Quantitative analysis
- Only allowed to include owner consequences (agency) by ER rules

Past and Current Projects:

- *CDOT: 2013 Floods*

  Approved by CO FHWA Division Office
- *CDOT: 2013 Rockfall Events*
- *Iowa DOT: March and June 2018 Floods*

Proactive (AM)

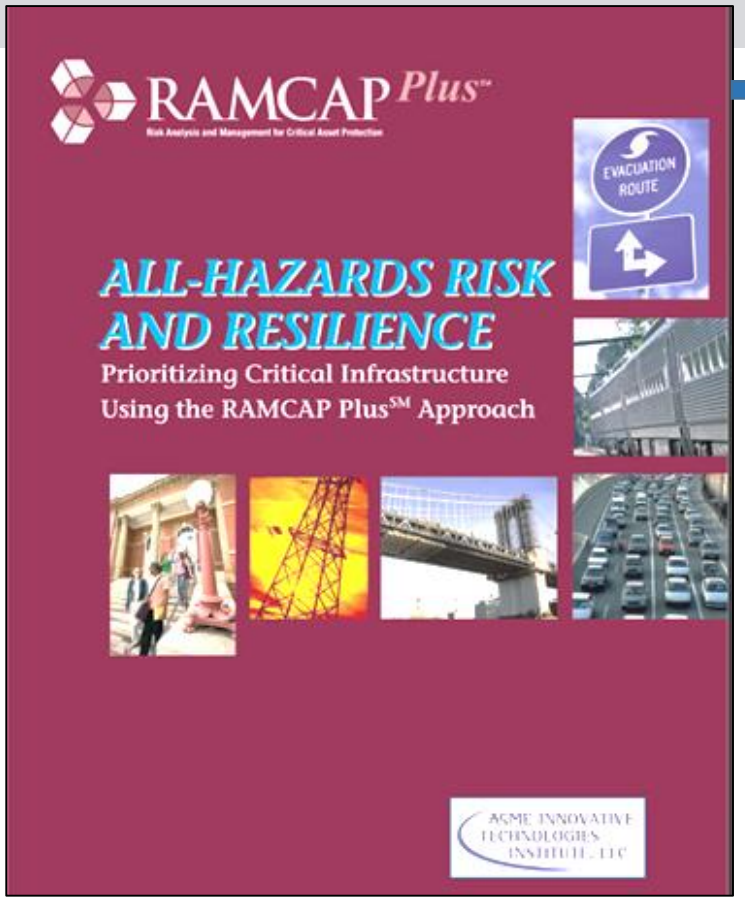
RnR for Highways for Asset Management

- Derived from *RAMCAP Plus*^{SM} (***R***isk ***A***nalysis and ***M***anagement for ***C***ritical ***A***sset ***P***rotection), ASME Industry Standard
- Systematic, **quantitative** and **probabilistic** analysis at the **asset level**
- May include multiple types of consequences: owner (agency), user (drivers), etc.

Past and Current Projects:

- *CDOT I-70 Pilots*
- *UDOT I-15 and US-40 Pilots*
- *CDOT Development of RnR Standard Procedure*
- *CDOT Debris Flow Post-Fire RnR Analysis*

RAMCAP Plus ➡ R&R for Highways



1. Asset Characterization	• What assets exist, which are critical, and what should be considered?
2. Threat Characterization	• What threats and hazards should be considered?
3. Consequence Analysis	• What happens to assets if a threat or hazard occurs? What are the expected asset losses, economic impacts, injuries, and lives lost?
4. Vulnerability Analysis	• What are the asset vulnerabilities that would allow a threat or hazard to result in expected consequences? How vulnerable is the asset to the identified threat?
5. Threat Assessment	• What is the likelihood of the identified threat?
6. Risk/Resilience Assessment	• What is the anticipated asset total risk and resilience? • **Risk= Consequences x Vulnerability x Threat** • **Resilience= Service Outage x Vulnerability x Threat**
7. Risk/Resilience Management	• What options are there to reduce risk and increase resilience? What is the risk reduction? What is the economic analysis of mitigation alternatives?

Step 3. Consequences

- Currently RnR Process includes the following consequences:
  - **Owner or Agency Consequences** (Asset Losses/Replacement Cost)
  - **User Consequences** (Travel Delay and Costs)

- Other possible consequences that could be included:
  - **Safety**
  - **Economic**
  - **Environmental**

Step 4. Vulnerability Assessment

- Estimation of the probability of an asset to experience certain damage or failure
- Based on asset characteristics such as condition, material, design, etc. and event magnitudes

Step 6. Risk & Resilience Assessment:
Risk Assessment

Risk (R) = C x V x T

Risk *(R)* *($)* → *Level of operational uncertainty in a threat-filled environment*

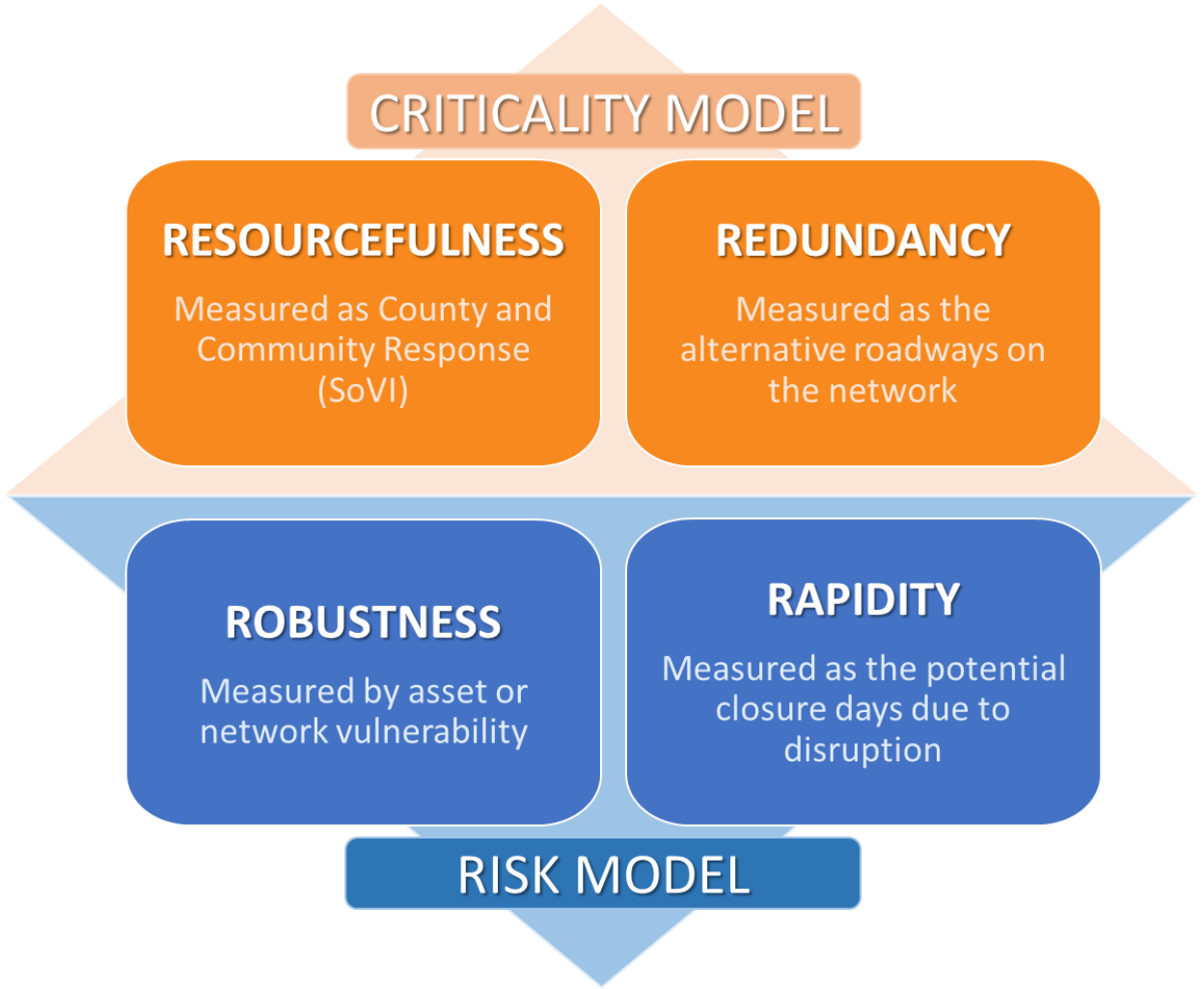
Consequence (C) ($) → *Result of damage or failure*

Vulnerability (V) (%) → *Susceptibility to the threat*

Threat Likelihood (T) (%) → *Potential of threat occurrence in any given year*

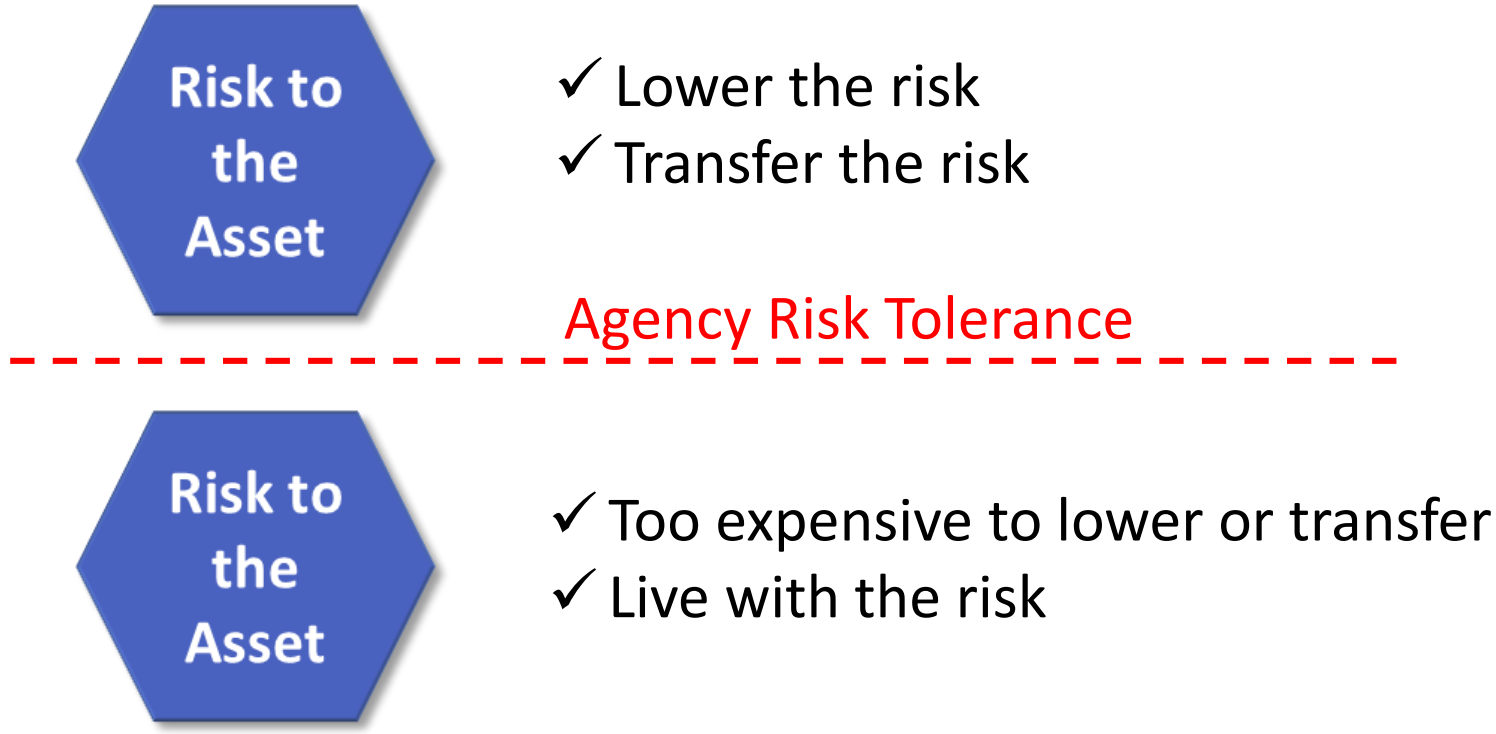


Step 6. Risk & Resilience Assessment
Resilience Assessment (Resilience Index-RI)



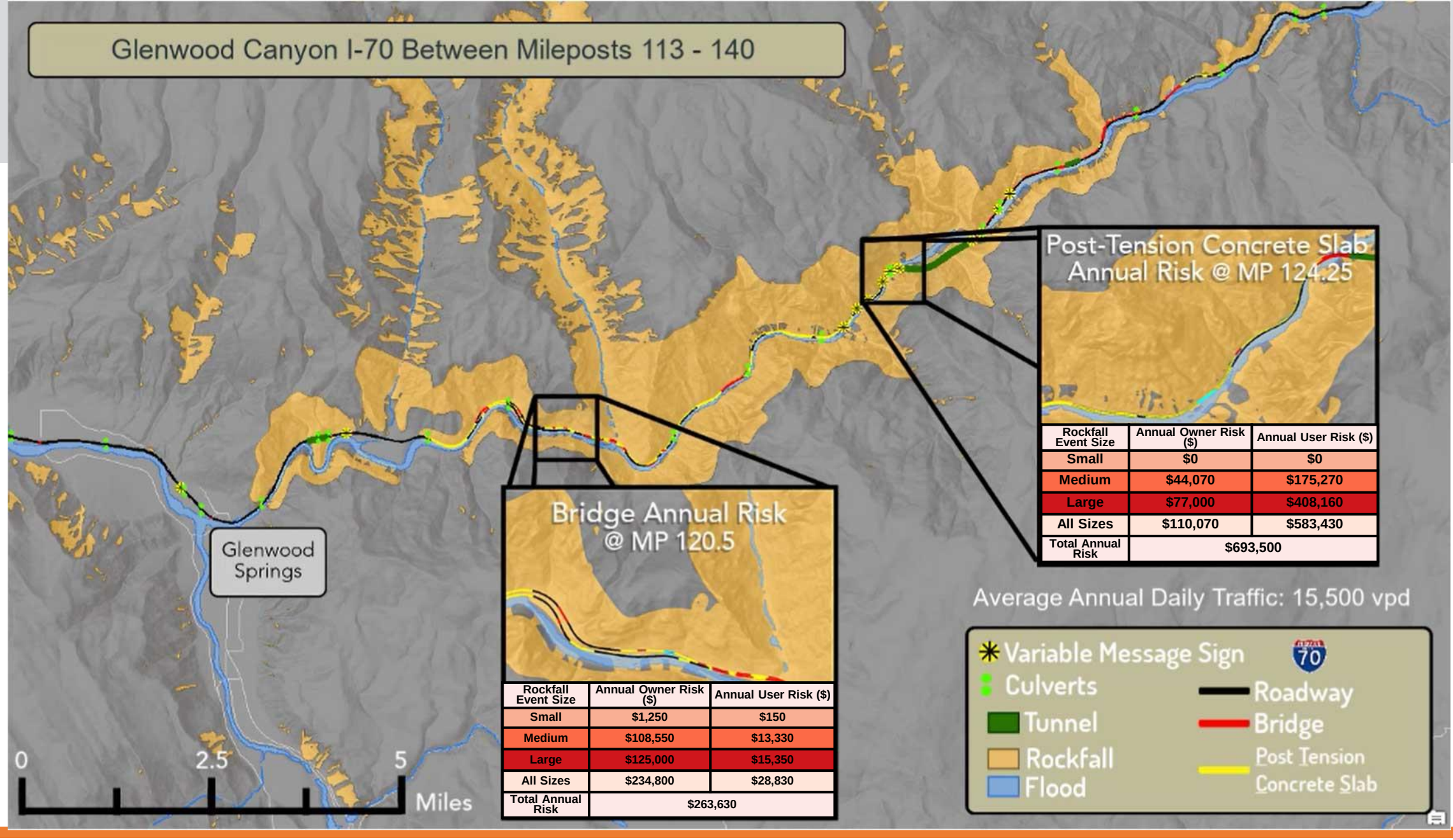
Step 7. Risk Management

Process of evaluating the baseline (risks currently faced by the critical assets) and deciding what, if anything, to do about it



Examples of RnR for Asset Management Applications

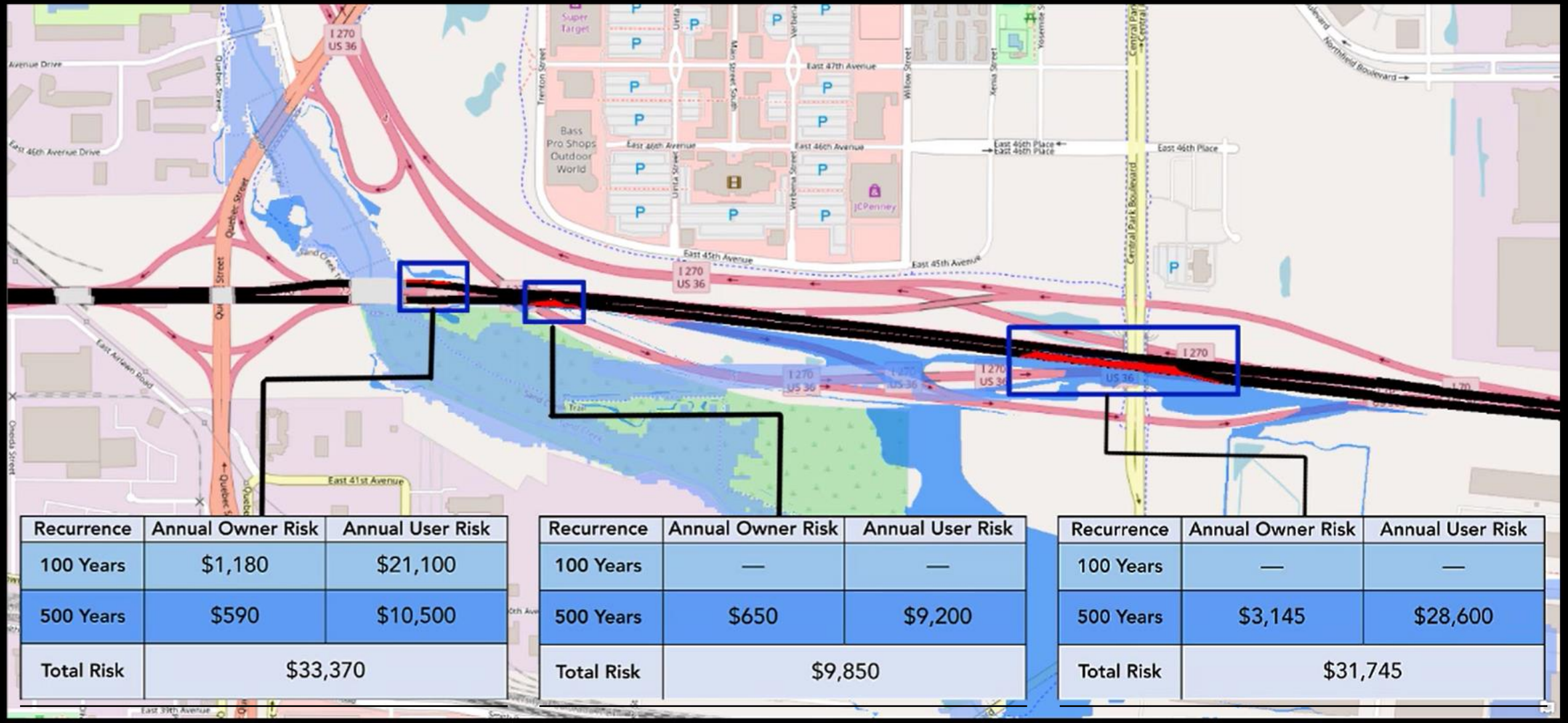
CDOT I-70 Rockfall & Flood



Rockfall Event Size	Annual Owner Risk ($)	Annual User Risk ($)
Small	$1,250	$150
Medium	$108,550	$13,330
Large	$125,000	$15,350
All Sizes	$234,800	$28,830
Total Annual Risk	$263,630	

Rockfall Event Size	Annual Owner Risk ($)	Annual User Risk ($)
Small	$0	$0
Medium	$44,070	$175,270
Large	$77,000	$408,160
All Sizes	$110,070	$583,430
Total Annual Risk	$693,500	

Flooding in eastern Denver on I-70



Recurrence	Annual Owner Risk	Annual User Risk
100 Years	$1,180	$21,100
500 Years	$590	$10,500
Total Risk	$33,370	

Recurrence	Annual Owner Risk	Annual User Risk
100 Years	—	—
500 Years	$650	$9,200
Total Risk	$9,850	

Recurrence	Annual Owner Risk	Annual User Risk
100 Years	—	—
500 Years	$3,145	$28,600
Total Risk	$31,745	

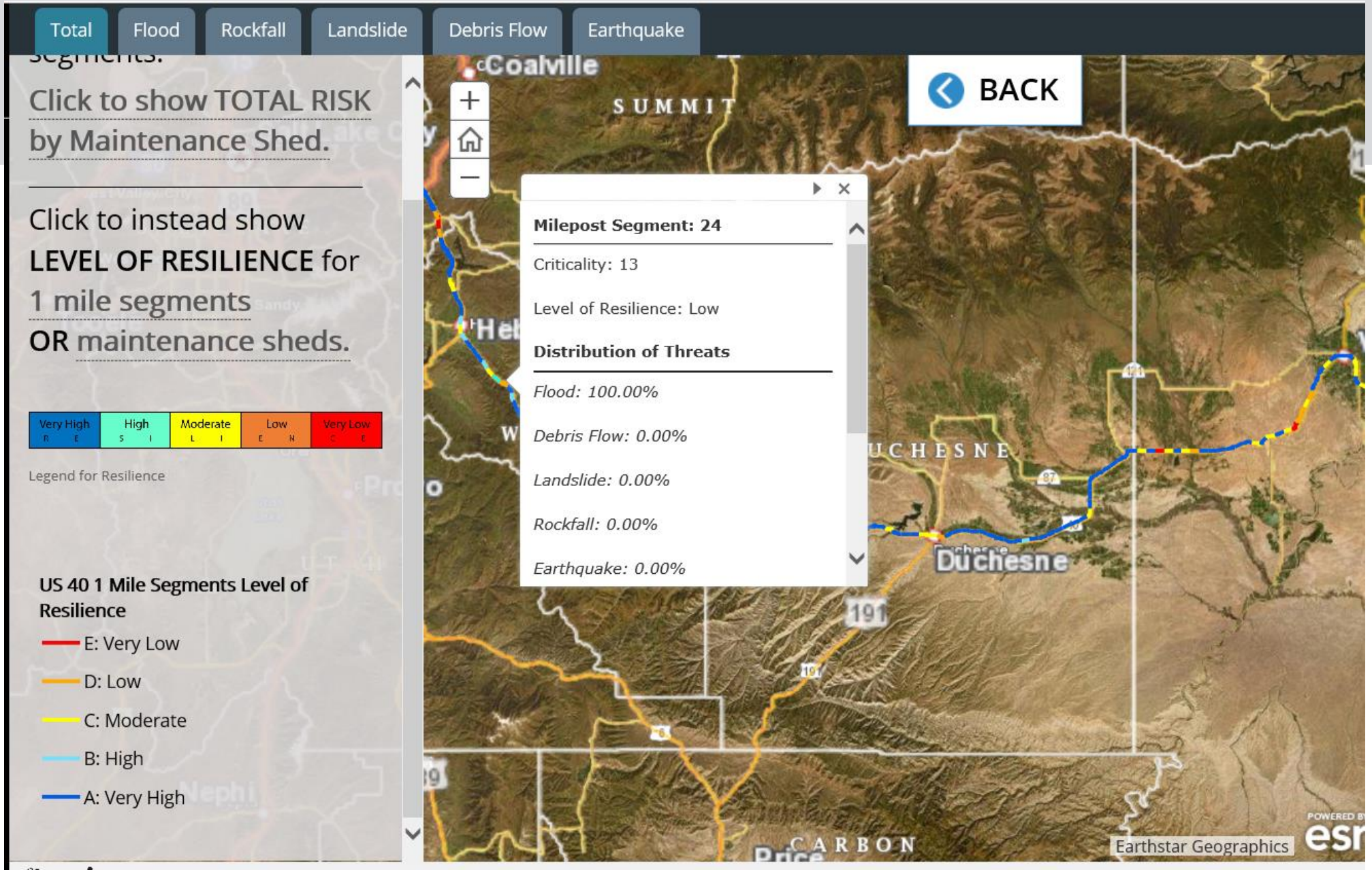
100 year flood | 500 year flood | Flood Intersect | I-70 | Bridge | Between Milepost 279 and 280

B/C Analysis: Non-NBI Culvert – Flood

Culverts Characteristics	Site Annual Owner Risk	Site Annual User Risk	Site Annual Total Risk
54” CMPs 100 cfs (<25-yr)	$9,880	$1,315,270	$1,325,150

Mitigation Options	B/C Owner Risk	B/C Total Risk
Option 1 72” concrete pipe	0.17	35.6
Option 2 8’ x 8’ CBCs	0.14	23.4

UDOT Corridor Planning – Including Resilience



Story Map - UDOT

https://uplan.maps.arcgis.com/apps/MapJournal/index.html?appid=1c3708f465c94780a3008d22838ee153

Benefits of a Quantitative Assessment

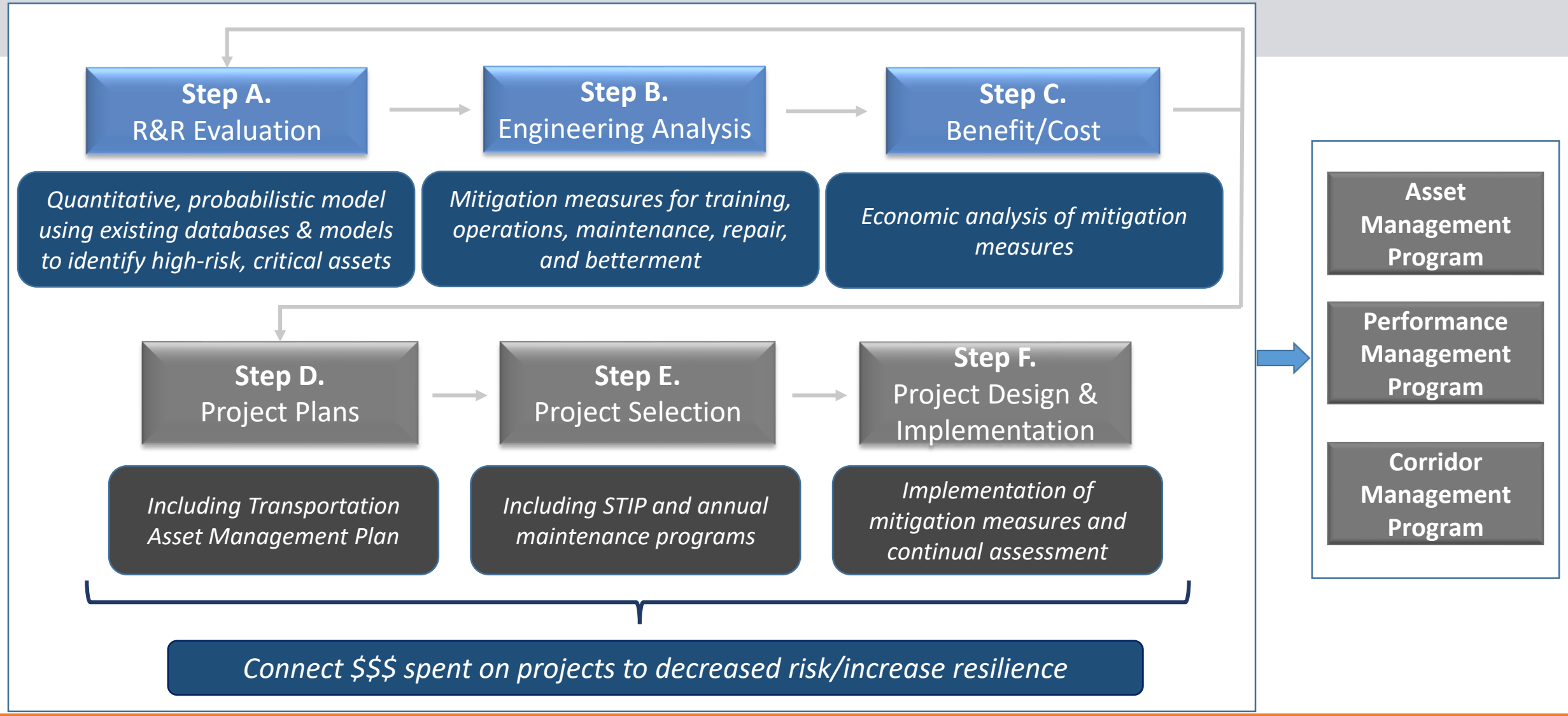
- Simple to incorporate findings into traditional engineering economic assessment
  - Benefit cost assessment
  - Life cycle cost analysis
- Quantitative annual financial risk easy for decision makers to interpret
- Risk assessment can be integrated with required performance measures to forecast performance including:
  - Travel time reliability
  - Safety
  - Freight travel time reliability
  - Infrastructure health

Findings from Asset Management Pilots

- Both DOTs identified multiple program areas for use of RnR data
  - Operational planning
  - Asset management
  - Maintenance prioritization
  - Planning Environmental Linkage studies (PEL)
  - Design

- Both DOTs currently expanding analysis to NHS facilities for inclusion in next edition of Risk Based Asset Management Plans

R&R for Highways ➡ Risk-Based Asset Management



AEM POCs

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Questions?

Resilience Research and Pilots

- CDOT Emergency Relief (ER) Risk-Based B/C Analysis (2014-present)
- CDOT Risk and Resilience Pilot for I-70 corridor (2016-2017)
- CDOT RnR User Guide for FHWA (2016-present)
- UDOT Risk and Resilience Pilot for I-15 corridor (2016-present)
- TRB Journal Publications (2015, 2017, 2018)
- NCHRP Synthesis Topic 48-13: Resilience in Transportation Planning, Engineering, Management, Policy, and Administration (In Publication)
- UDOT Extreme Weather and Durability Project (2018-2019)
- CDOT Risk and Resilience Standard Analysis Project (2018-2019)
- Iowa DOT Emergency Relief (ER) Risk Based B/C Analysis (2019-present)